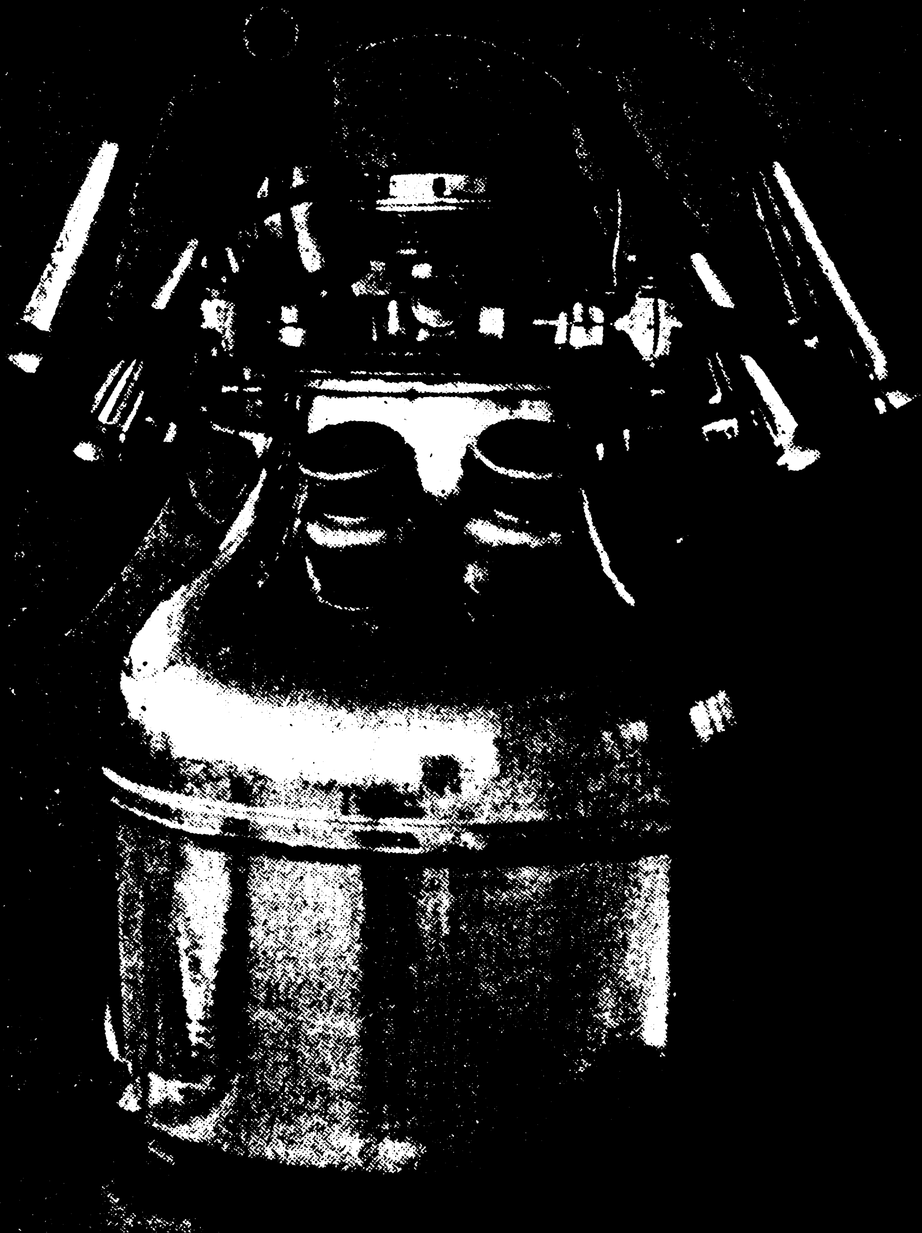
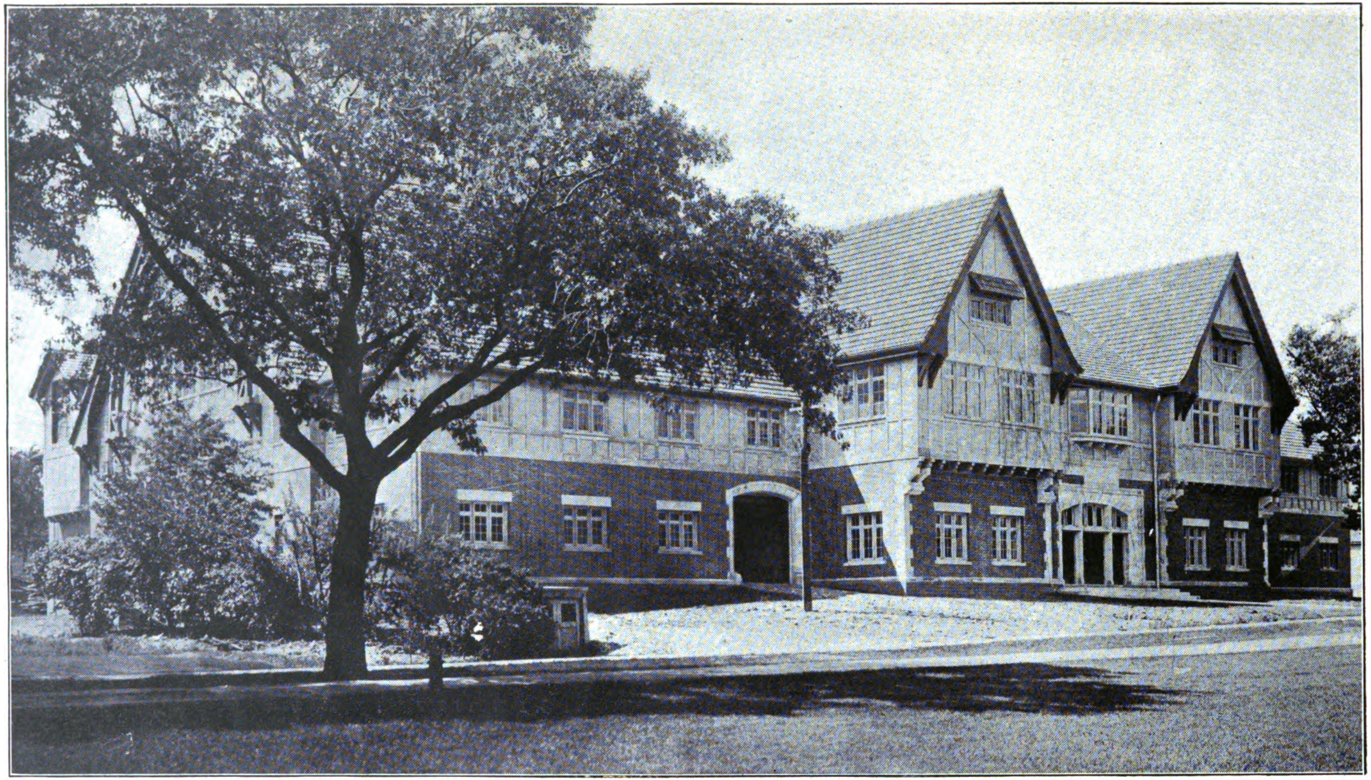


Annual Report of the Agricultural Experiment ...

University of Wisconsin--Madison. Agricultural Experiment Station



THE NEW LIVE STOCK PAVILION, COMPLETED IN 1910, AT A COST OF $80,000.

TWENTY-FIFTH AND TWENTY-SIXTH

ANNUAL REPORTS

OF THE

Agricultural Experiment Station

OF

THE UNIVERSITY OF WISCONSIN

For the years ending June 30, 1908, and June 30, 1909

WITH RESEARCH BULLETINS NOS. 1 TO 6, INCLUSIVE

Issued 1908–9

MADISON
DEMOCRAT PRINTING COMPANY, STATE PRINTER
1910

NEW PLAN OF PUBLICATION

The Annual Report of this Station will hereafter consist of the Report of the Director and the Research Bulletins issued during the fiscal year and will be printed in a limited edition for distribution to libraries, public institutions and individuals who especially desire to keep a complete file of these reports. The Reports of the Director are widely distributed as popular bulletins and the Research Bulletins are sent to those particularly interested in the subjects treated.

In this volume the Reports of the Director for two fiscal years together with Research Bulletins issued during 1908–1909 have been bound together, since no Research Bulletins were issued in 1907–1908 to be bound with the Report of the Director for that year.

CONTENTS

THE UNIVERSITY OF WISCONSIN

Agricultural Experiment Station

STAFF

THE PRESIDENT of the University
H. L. RUSSELL, Director
S. M. BABCOCK, Assistant Director
IDA HERFURTH, Executive Clerk

W. A. HENRY, Emeritus Professor of Agriculture

A. S. ALEXANDER, Veterinary Science, In charge of Stallion Licensing
S. M. BABCOCK, In charge of Agricultural Chemistry
L. J. COLE, In charge of Experimental Breeding
E. J. DELWICHE, Supt. Northern Sub-Stations, (Ashland, Wis.)
E. H. FARRINGTON, In charge of Dairy Husbandry
J. G. FULLER, Animal Husbandry
J. G. HALPIN, In charge of Poultry Husbandry
E. B. HART, Agricultural Chemistry
E. G. HASTINGS, Agricultural Bacteriology
K. L. HATCH, Agricultural Education; Secretary Agricultural Extension
G. C. HUMPHREY, In charge of Animal Husbandry
E. R. JONES, Soils
L. R. JONES, In charge of Plant Pathology
C. E. LEE, Dairying
ABBY L. MARLATT, In charge of Home Economics
E. V. MCCOLLUM, Agricultural Chemistry
J. G. MOORE, In charge of Horticulture (Pro tem.)
R. A. MOORE, In charge of Agronomy
C. P. NORGORD, Agronomy
C. A. OCOCK, In charge of Agricultural Engineering
D. H. OTIS, Farm Management
M. P. RAVENEL, In charge of Agricultural Bacteriology
J. L. SAMMIS, Dairy Husbandry
J. G. SANDERS, In charge of Economic Entomology
JOHN SPENCER, Veterinary Science
C. W. STODDART, Soils
H. C. TAYLOR, In charge of Agricultural Economics
A. R. WHITSON, In charge of Soils
F. W. WOLL, In charge of Feed and Fertilizer Inspection; Dairy Tests

G. H. BENKENDORF, Dairy Husbandry
EMILY E. BRESEE, Feed and Fertilizer Inspection
L. R. DAVIES, Dairy Tests; Feed and Fertilizer Inspection
E. E. ELDREDGE, Agricultural Bacteriology
C. S. HEAN, Agricultural Library
LEONA HOPE, Home Economics
J. JOHNSON, Horticulture
J. C. JURRJENS, Feed and Fertilizer Inspection
F. KLEINHEINZ, Animal Husbandry
ALICE LOOMIS, Home Economics
O. G. MALDE, Cranberry Investigations, (Grand Rapids, Wis.)
J. C. MARQUIS, Agricultural Editor
J. G. MILWARD, Horticulture
W. E. MORRIS, Feed and Fertilizer Inspection
J. M. NAPIER, Agronomy
C. R. ORTON, Plant Pathology
P. P. PETERSON, Soils
W. H. PETERSON, Agricultural Chemistry
A. J. ROGERS, JR., Horticulture; In charge of Nursery Inspection
F. J. SIEVERS, Soils
H. STEENBOCK, Agricultural Chemistry
W. W. SYLVESTER, Agricultural Engineering
A. L. STONE, Agronomy; In charge of Seed Inspection
J. L. TORMEY, Animal Husbandry
W. E. TOTTINGHAM, Agricultural Chemistry
E. TRUOG, Soils
H. L. WALSTER, Soils
W. W. WEIR, Soils
F. WHITE, Agricultural Engineering
W. H. WRIGHT, Agricultural Bacteriology

FARMERS' INSTITUTES

GEORGE MCKERROW, Superintendent
NELLIE E. GRIFFITHS, Clerk

The bulletins of this Station are sent free to residents of the State. Names will be entered on the regular mailing list upon request.

PART I

REPORTS OF THE DIRECTOR

1907–1908

AND

1908–1909

REPORT OF THE DIRECTOR.

H. L. RUSSELL.

The Twenty-Fifth Annual Report of the Agricultural Experiment Station of the University of Wisconsin is herewith presented, covering the fiscal year ended June 30, 1908. This report marks the completion of a quarter of a century of experiment station effort in this state. The continuity of purpose which has marked the activities of this Experiment Station throughout its entire career is largely attributable to the fact that it has not been subject to the frequent changes in administration that have characterized so many other such institutions. From the organization of this Station, until last year, its direction has been under Professor William Arnon Henry, who, by reason of the condition of his health, was obliged to retire from administrative work last year. In the Twenty-Fourth Annual Report record was made of the services of Professor Henry, and the appreciation of the Regents of the University of Wisconsin expressed in the form of an engrossed resolution. In view of the fact that this report marks the completion of the quarter centenary of this institution, it seems proper again to refer to the distinguished services which he has rendered in the development of Wisconsin's Agricultural Experiment Station.

ADMINISTRATION.

The teaching work of the College performed at the University and the many lines of work carried on throughout the state-at-large, are very rapidly growing, and are requiring an increased amount of attention. The increase in number of students taking college work is exceedingly rapid, not only in the Short Course, which now numbers over 450, but in the regular full time University courses. Much of the work done throughout the state is of the nature of extension of the re-

search work of the Station directly to the people of the state, and is therefore of utmost importance in the development of our agriculture. It is becoming more and more necessary as these respective lines grow that they be more completely organized and correlated. This coming year it is to be hoped that the legislature will make proper provision for the extension work so that it will be possible for those engaged in the disinctively research work of the Station to give their time more uninterruptedly to research problems, the successful accomplishment of which demands freedom from other regular duties.

CHANGES IN STATION PUBLICATIONS.

The work of the Experiment Station is primarily designed to extend the boundaries of agricultural science. While a leading part is always concerned with problems that are of more or less immediate practical value, a not inconsiderable amount of research is quite technical in character, and often is not susceptible of immediate presentation in a form suitable for general distribution to farmers. Suitable differentiation of these two types of work has not heretofore been made, and after careful consideration it has been deemed advisable to change the method of issuing the publications of this Experiment Station. Heretofore two series of publications have been issued:

1. Bulletins issued at frequent and irregular intervals in editions of varying size, describing some definite single phase of Station work, usually in popular form.

2. An Annual Report of 15,000 copies, containing, in the main, the technical and scientific work of the Station, as well as articles of the more popular class. Naturally a not inconsiderable portion of this latter publication is of such a character as to be of but small interest to the practical farmer, however valuable it may be to the scientific student of agriculture. The expense of such large editions is not inconsiderable and after careful consideration, it has been deemed advisable to alter materially the plan of issuing the publications.

Beginning with this fiscal year, the following changes will be made: More emphasis will be given to the presentation of the practical results obtained from the experimental work, and these will be presented as short, illustrated bulletins prepared in popular form. It is to be hoped that these may be much more

widely distributed than has heretofore been the case, so as to bring the results of the Station's activities in the best possible form to the largest number of persons interested therein. The more technical and scientific findings that are merely of value to the scientific worker will be published separately in a new series of bulletins, entitled "Research Bulletins," which will be issued in limited editions and not given general distribution. These bulletins will present scientific data of importance to those who are engaged in studies in similar lines, but persons not actually engaged in scientific work who may desire these technical publications may obtain them, so long as the the supply is available, upon application to the Station.

In order that these results may be brought together in permanent form, there will be issued at the end of each fiscal year, an Annual Report, which will be made up of two parts:

Part 1, the Director's Report, which will include a general summary of all the activities of the Station in its various lines, together with such financial and other statements as may be required by law. This report will also be issued in bulletin form and given general distribution.

Part 2, the Research Bulletins that have previously been issued from time to time during the year. These two parts will be bound in paper or in cloth, as prescribed by law, and distributed to libraries, public institutions, etc., for historical purposes, and to such persons who are especially desirous of maintaining a file of the research work of the Station. It is believed that this new method will economize in the matter of public printing and distribute the results of experiment station effort in the most economical way to those interested therein.

CHANGES IN STATION PERSONNEL.

Only a very few changes are to be recorded in the personnel of the Station staff for this year. Mr. George A. Olson, of the Agricultural Chemistry Department severed his connection with the institution this year, and W. A. Brannon was appointed in his place as Assistant in Feed and Fertilizer Inspection in the analytical laboratory. Mr. C. S. Knight, Assistant in Feed and Fertilizer inspection resigned in January, 1908, to accept a position in the Kansas Agricultural College, and his place was filled by the appointment of Mr. George Hine. Mr. R. R. Marshall

was appointed Assistant in the Soils Department in connection with field experiments.

PERMANENT IMPROVEMENTS AND ADDITIONS TO RESOURCES.

The College of Agriculture associated with this Experiment Station has always been more or less handicapped in the matter of land, on account of the fact that the University is located within the city limits, and is limited to a very considerable extent by its situation on the shores of Lake Mendota. Some ten years ago a tract of 160 acres of land, known as the Hill Farm, lying two miles west of the University, was purchased for the use of the Agricultural Department. To this an addition of 60 acres was later made, and this last year opportunity presented itself to secure a favorable option on a 70-acre tract lying immediately adjacent to the original farm. This was leased for a period of five years, with the privilege of buying the same at a fixed price within that time. These lands are urgently needed to give opportunity for the necessary expansion of the work of the Animal Husbandry Department, and for the production of pure-bred grains for dissemination throughout the state. With the constant expansion of the University, more and more of the original farm which has been used for experimental purposes since the inauguration of the Station, will be required for general University use, and very soon it will be necessary to replace these lands by additional purchases, which can only be made to the westward of our present holdings.

During this year one new building has been authorized by the Board of Regents, and there is now in process of construction a Stock Pavilion which is expected to be finished during the coming summer. This Stock Pavilion contains a large amphitheater having a seating capacity of 2,000, and will give exceptionally good facilities for the handling of large gatherings. This building will include, in addition to the amphitheater, which can be divided off into sections for stock judging purposes, ample quarters for housing the horses belonging to the different departments, hospital and veterinary facilities, offices for the farm superintendent, and several offices for various members of the Animal Husbandry Department.

In addition to this building the surplus saved in the operation of the Agricultural College for the last year has been used in constructing three new greenhouses for the soil departments,

that have been practically rebuilt; also an 80-ton stave silo at the Dairy Barn, which is used for the making of silage for summer use. This last season has given us a splendid opportunity to test the value of this method of feeding dairy animals, and the milk flow of the University herd has never been maintained so high during the drought of summer as has been the case this year.

ADDITIONS TO FINANCIAL RESOURCES.

The passage of the Adams and the Nelson acts by Congress is increasing the amounts of money which are granted from the national treasury for the further development of agricultural experimentation and education. In addition to the Hatch act, which was the original foundation of the agricultural experiment stations, the Adams act, gives us this year $11,000 additional, the money so received to be applied only "in paying the necessary expenses of conducting original researches on experiments bearing directly on the agricultural industry of the United States." It is for the "more complete endowment and maintenance of the experiment stations, presupposing the provision of a working plant and administrative officers." This fund, as indicated, can only be used in prosecuting the strictly scientific work of the experiment stations, and unquestionably will do more toward elevating the character of the scientific work of these organizations than any other factor. Under the Nelson act, passed by Congress on March 4, 1907, there was appropriated to each agricultural college a gradually increasing fund which is now $10,000, which is designed to supplement the Morrill act of 1862, on which all of the land grant colleges were founded. These funds are given by the federal government to aid and stimulate the development of agriculture, and the moral obligation imposed upon each state receiving the same is to supplement such fund so far as it is within its power. This. in the case of the State of Wisconsin, has been made by gradually increasing appropriations devoted to the work of the Agricultural College. The work of the College is so closely coordinated between experimental research in the Experiment Station, teaching in the College proper, and the extension service which is carried on throughout the state, that it is very difficult to determine the exact cost of the administration of these respective lines of work, but within the last few years, an increasing por-

tion has been devoted to various types of demonstrative work which have been in progress throughout all portions of the state. The time has come when this type of work should be more completely organized and special provision made for its further development.

RESEARCH WORK OF THE EXPERIMENT STATION.

It is exceedingly difficult to measure the net results of the experimental work of any institution, and record how valuable and fruitful its energies have been. The teaching work expresses itself more concretely, and may be compared in definite mathematical terms as to the number of students who are instructed. For some years the teaching demands of the College, occasioned by the rapid growth of the long course, have increased so rapidly that it has been quite impossible to adjust the staff of the College as at present organized, to these conditions. For the best grade of research work, uninterrupted time in periods of considerable length is necessary, and it has been increasingly difficult for members of the staff to secure this. Notwithstanding these drawbacks, a considerable amount of important scientific work has been accomplished, only a portion of the results of which has been published.

Under the supervision of the federal department of agriculture, of the funds expended under the Adams act, a much closer control as to the nature of the scientific work carried on is being made than was formerly the case. Projects must be submitted in advance to the Office of Experiment Stations, and approved by them before being authorized. It is evident that too careful consideration cannot be given to the planning of work beforehand, and the inauguration of this method of control will doubtless prove to be highly beneficial. During the last fiscal year this system of detailed projects has been extended to all of the research work of this Station.

GENERAL PROGRESS OF RESEARCH WORK.

Many projects are under consideration by members of the various departments which are not brought to a state of final completion within the limits of any particular year. In many instances research work of this character will frequently cover a period of a number of years, and inasmuch as the results are not in such form as to permit of definite conclusions being drawn,

it is frequently inadvisable to present a fragmentary account of such researches. It therefore follows that no report of the Experiment Station can give anything like an adequate account of the activities of the staff along the line of research and investigation. The results which have reached final form will be presented through the usual mediums, either as research or popular bulletins and therefore do not need to be considered in this connection. It may, however, be desirable to present a progress report of certain phases of work which have been undertaken, so as to indicate somewhat the scope of the station activities.

An important joint investigation which has been in progress for the last two years, between the Agricultural Chemistry and Animal Husbandry Departments, is a series of physiological studies on animal nutrition.

ROLE OF PHOSPHORUS IN DEVELOPING SWINE.—So far, emphasis in scientific nutritional studies has been placed mainly on the rôle of organic substances in the animal body—fats, proteins, or carbohydrates. It is equally important that attention should be directed to the part played by other food constituents, more particularly the inorganic elements. In these studies phosphorus has been under consideration, and Professors Hart and McCollum, in cooperation with Professors Humphrey and Fuller, have made important discoveries. Pigs were fed on a depleted phosphorus ration alone, also one supplemented with inorganic phosphates. Up to a certain point the phosphorus-low ration permitted apparently normal tissue development. In the course of some weeks, however, physiological disturbance became evident, and loss of weight and final collapse took place. Prior to this metabolic disturbance, the phosphorus content of tissues and body fluids remained parallel with that of control animals, in spite of the low phosphorus intake in the food. Such maintenance was traced to a withdrawal of the phosphates from the skeleton of the animal, as was indicated by the low ash content of the bones. Where physiological disturbance was observed, loss of appetite occurred, locomotion became impossible, and a gradually deepening stupor preceded the final collapse of the animal. Where the symptoms were not too pronounced, the animals recovered when supplied with feeds containing the organic phosphorus. Pigs fed from the first on depleted phosphorus rations supplemented with inorganic phosphates, such

as ground phosphate rock (floats) made as vigorous growth as animals receiving organic phosphorus compounds.

While these experiments bring out certain facts of scientific importance, they open up a very promising field of practical investigation, as to the possibility of substituting the cheaper inorganic phosphates for the more expensive forms of phosphorus found in ordinary feeds. The results here presented will appear in a research bulletin in the near future.

CHEMICAL STUDIES ON LAXATIVE EFFECT OF WHEAT BRAN.—Feeders have long recognized the laxative effect which wheat bran exerts upon an animal fed this material. This feed is known to contain large quantities of an organic phosphorus compound known as phytin, and metabolism experiments made on milch cows fed upon rations rich in bran, and therefore in phytin, and also where the phytin had been removed by washing, demonstrated that the laxative effect of bran was attributable to the presence of this substance. In these chemical studies so far it has been impossible to dissect phytin and determine whether this pharmacological effect is due to the basic substances present or to the compounds of phosphorus.

VALUE OF CHEMICALLY BALANCED RATIONS MADE FROM SINGLE VS. MIXED PLANT SOURCES.—The chemist has materially advanced the science of feeding by determining the relative proportion of carbohydrates and protein needed in compounding a suitable ration for developing animal life. Practical experience has demonstrated that the most profitable ration should contain a certain ratio of these substances, but more emphasis has been laid upon the results of chemical analysis than upon the possible physiological effect of the different constituents in feeding stuffs from different plant sources. Is the proteid or starch of one cereal grain identical in its physiological effect with that of other grains? For nearly two years the Animal Husbandry and Chemical Departments have been studying this question. Sixteen young calves have been reared upon a balanced ration composed of nutrients from single as well as mixed plant sources. By the usual methods of chemical analysis these rations are absolutely identical, and different lots of animals have been fed upon corn, wheat, and oats, respectively, also a combination of all three nutrients. From an early stage marked physiological differences appeared. The different groups have reached a stage of physiological maturity at widely differing times, and it is apparent at this writing that the animals

receiving a ration made from mixed grains are more normal than some of those receiving "single" plant rations. These experiments will be continued long enough to place all of the animals under the strain of reproduction, so that the effect of the nutritive method may be continued throughout a complete cycle.

MILKING MACHINE EXPERIMENTS.—The heavy burden placed upon the dairy industry in the necessity of hand milking dairy animals has been such as to lead numerous inventors to attempt to solve the problem of milking by machinery. Within the last few years several machines have been placed upon the market for which high claims have been made as to their efficiency in reducing this process to a mechanical basis. Investigations have been under way at this station with one of these machines for a period of a year and a half, and a large body of data has been accumulated which gives a good foundation for conclusions of value. The results of this study will soon appear in bulletin form, and need not be detailed here.

From a mechanical point of view, it is evident that a single operator can handle three machines with ease, but the successful use of the cow milker requires more than an ordinary degree of care, and it may be expected that dissatisfaction may result where careless handling obtains. No appreciable ill effect was noted on the animals, and almost all soon took kindly to the machine, and after a few weeks duration were as cleanly milked by machine as by hand, although occasional individuals were more resistant. It is, of course, absolutely necessary that the apparatus be kept in a perfectly clean condition, and where this is done, the sanitary condition of the milk supply can be as satisfactorily maintained as in hand milking.

NUTRITION STUDIES ON THE DAIRY HERD.—Studies in nutrition on the influence of medium and high protein on milk secretion have been continued this year by Professors Humphrey and Woll. A three-year period on the use of high protein was completed in 1906, and for two years the herd has been handled on a medium protein basis. Another year's results will give a broad basis for comparative studies as to which is best for the economic production of butter fat.

The improvement of our University herd continues. Seven cows qualified this last year for the advanced registry class. One of the Jerseys, Double Time, now nine years old, this year made

the record of the second best of this breed in America. In a 7-day test she produced 410.9 pounds of milk, containing 20.388 pounds of butter fat, lacking less than 2 ounces of equaling the best producer of her breed.

DAIRY FACTORY TESTS.—During this year two new methods have been devised at this Station for the testing of milk under factory conditions. The Hart casein test, described in Bulletin 156, is the first simple factory method that has yet been devised for the analysis of milk with reference to its casein content. A new moisture test, for the determination of water in butter, described in Bulletin 154, gives another rapid method for the estimation of the moisture content of butter.

Six different types of tests have been devised and applied more or less generally in dairy factory operations. These are as follows: the Babcock test, for the determination of fat; the Wisconsin curd test, for the detection of taints; the acid test, for the determination of acidity of milk and cream; the rennet test, used to indicate the proper maturity of milk in the process of cheese making; the moisture test, for the determination of the water content of butter, and the Hart test, for the estimation of the casein. It is worthy of note that representatives of five of these different types of tests have been perfected by members of the staff of this Experiment Station, and that three of the five tests are practically the only methods in use for their respective purposes.

PLANT BREEDING.—Professor R. A. Moore has been working for several years on pedigreed barleys to secure a type that will be uniform in quality. He has succeeded in developing strains that are an improvement on the Manshury and Oderbrucker varieties, and this year 50 acres of these pedigreed types were grown, so that limited amounts of seed will be available for distribution this coming year. Work is also in progress on other varieties of small grains; buckwheat, peas, and forage crops are also under investigation.

Professor Sandsten is at work on the subject of selection of improved strains of potatoes. Attempts are being made to secure, if possible, varieties that possess increased resistance toward the blight. The potato industry of this state has already reached a value of about $8,000,000, and is capable of great extension. The average yield is yet small, only about 90 bushels per acre. By the use of improved seed and better cultural

methods, it should be increased to at least 150 bushels per acre. The Horticultural Department has also had hybridization experiments on tobacco under way for several years. Several crosses have been secured, and two or three new varieties of seeming special excellence have been developed. Not only are the leaves larger and better shaped, but the quality, texture, and size of vein are greatly improved. From the season's work this year a small quantity of seed has been secured, which will be distributed in a few places this coming year. If this should succeed under the varying conditions of ordinary farm culture, we shall arrange for the growing of this seed in larger quantities.

TOBACCO CURING.—By improper methods of curing, large sums of money are now annually lost. Much of the deterioration in the quality of tobacco happens after the crop is harvested and in the shed, and studies have been made by Professor Sandsten of the Horticultural Department to see if it is not possible to control the conditions under which tobacco is shed cured. A model shed was erected several years ago sufficiently large to accommodate the crop from about 2 acres. This shed was equipped with steam pipes, and a traction engine was used for furnishing the heat when needed. By the application of this method a much more uniform color was obtained, and the curing of the tobacco rendered independent of variations in weather conditions. In the crop so treated practically no loss resulted from the usual troubles which occur in curing.

FERTILIZERS IN TOBACCO CULTURE.—It is customary in Wisconsin to use large quantities of stable manure on tobacco lands, and but little experimental work has been done with the use of commercial fertilizers. Experiments carried on in Columbia, Crawford, and Rock counties (representing different types of tobacco soils in the state) indicate that under present conditions the use of commercial fertilizers cannot be considered as advisable, for while there is an increased yield from the liberal use of such fertilizers, such increase is not commensurate with the outlay incurred. It is also of importance to note the relation of these commercial fertilizers to the quality of the tobacco, especially as to its burning properties. Fertilizers free from chlorine were found not to exert any detrimental effect upon this quality.

EXPERIMENTS IN CHEESE MANUFACTURE.—The cooperative work in cheese making with the United States Department of Agriculture has been continued and extended during the past year. This work has been under the immediate charge of Professor Sammis of the Dairy Department, although the Bacteriology and Chemistry Departments have assisted. The Dairy Division of the United States Department of Agriculture has three experts stationed here working in conjunction with our staff on these problems. The experiments this year have been made with particular reference to the use of pasteurized milk, and while not completed, it appears that milk may be heated to 155–160 degrees F. in a continuous pasteurizer, (stopping in large measure, bacterial development), and then brought to a standard degree of acidity by the use of commercial acid. The addition, then, of a properly selected starter supplies the necessary organisms and the further manufacturing operations can be successfully carried out in a uniform manner.

The pasteurized cheese so far made is uniformly clean in flavor, although the control cheese is often tainted. A slightly higher yield is obtained, due to the saving, in part, of some of the fat, and a somewhat higher moisture content of the curd. This process has not yet passed the experimental stage, and it is not yet certain what the effect of matured curing will show.

ORIGIN OF CHEESE FLAVORS.—Studies on origin of flavor in cheese have been continued by Professors Hastings and Hart. They have approached this subject from an entirely new point of view, and are studying the influence which carbohydrates, such as sugar, exert on production of flavor. In this they have succeeded in obtaining results that promise well.

INFLUENCE OF SOIL TREATMENT ON PHOSPHORUS CONTENT OF SOILS.—Professors Whitson and Stoddart have studied the influence of soil treatment on the phosphorus content of soils, and the conditions influencing the availability of phosphorus. Professor Stoddart has devised a new method which permits of the separation of the different phosphate salts from each other, and the field results already show that the combination of phosphates with humus sometimes renders phosphates unavailable to plants. Ninety-five per cent of the total loss in phosphoric acid on fields continuously cropped, with little or no manure, is accounted for by the crops which are removed. Soils receiving copious amounts of fertilizers, such as heavily manured

tobacco soils, receive much more phosphoric acid than the crop removes, but this phosphate excess does not apparently accumulate in the soil.

STUDIES ON DIFFERENT SOIL TYPES.—The Soils Department has been carrying on experiments on the restoration of worn out light soils at Sparta, and by a rotation of crops, and the utilization of legumes, have succeeded in improving materially the quality of the soil. Lupines and serradella are found to be much better adapted to these highly exhausted lands than any of the clovers.

Very favorable results have been obtained upon the heavy red clays at Ashland and Superior by tile drainage, and both cereal and forage crops this year show a heavy growth, indicating the beneficial effect of drainage; where phosphate fertilizers have supplemented manure, improved results were also secured.

Experimental work on marsh soils at four stations indicates that these soils as a class do not need nitrogen fertilizers or lime, but that they are deficient in both phosphate and potash. At Marinette this year extremely heavy crops of mixed timothy and alsike clover were secured, the yield on soils where phosphates and potash were used being two to three times the yield of control areas. This means much for central and northern Wisconsin where large areas are well adapted to this crop. The problem of these peat lands is, however, not always a simple one, as at Phillips soils were found that did not respond readily to this treatment because nitrification is not sufficiently active to insure satisfactory crops.

NEW METHOD OF CRANBERRY CULTURE.—Further experience with the new method of cranberry culture for Wisconsin (recommended by Professor Whitson) consisting of sanding the beds, thorough drainage, and clean cultivation, indicates that the frost problem in cranberry culture is now practically solved. The temperature of our experimental bogs, which have been improved in this way, is from 6–10 degrees F. higher than the overlying air, so that a frost as low as 26 degrees F. can be successfully passed. It now remains for those engaged in this industry to adapt themselves to these new conditions to secure immunity from the destructive summer frosts. In cooperation with the Bureau of Entomology of the United States Department of Agriculture, special emphasis has been given this season to the study of insect ravages, and important results in the life

history of the more destructive insects determined. Spraying experiments, for the control of insect pests, have been unusually successful.

BACTERIOLOGICAL STUDIES ON MILK.—Professor Hastings has studied a peculiar type of lactic acid producing organism capable of forming abnormally large quantities of lactic acid. Ordinarily about 0.8% of acid is produced by the lactic fermentation, but this type of organism produces from 3 to 4 per cent. They also grow well at high temperatures, from 100 to 110 degrees F. This class of bacteria do not seem to have been noted by other bacteriologists, although he finds them widely distributed in milk.

FIXATION OF NITROGEN BY MICRO-ORGANISMS.—Mr. Hoffmann has been studying the conditions affecting nitrogen fixation by that peculiar type of bacteria known as *Azotobacter,* and finds that the quantity of nitrogen in the culture is very materially increased. The rate of fixation is closely dependent upon the amount of carbon available for production of energy, as well as the source of the carbon supply.

STRUCTURE OF THE UDDER.—It is indeed surprising that experiment stations have not given more consideration to the finer structure of the cow's udder. While this organ has been studied from the purely scientific point of view, generally animals other than cattle have been chosen as illustrations. Mr. Smith, of the Bacteriological Department, has been engaged this past year in a miscroscopic study of the udder in different stages of development. Microscopic preparations of the quiescent, actively secreting and "discharged" udder glands, give a very instructive idea of the relation of milk secretion to the physiological activity of cells of this organ.

PUBLICATIONS ISSUED.

During the fiscal year covered by this report, there have been issued, in addition to the Annual Report of 437 pages, for the preceding year, 11 regular, and 2 special bulletins, aggregating 920 pages. These have been printed in editions ranging from 2,000 to 50,000 copies, the larger editions being intended to supply the call for such bulletins as are likely to be in general demand for a considerable period of time.

No.	Title.	Author.	Size of edition.	Number of pages.
153	Portable Hog Houses	Fuller and Ocock	30,000	28
154	A Creamery Method for the Determination of Water in Butter	Farrington	10,000	19
155	The Distribution of Stallions in Wisconsin	Alexander	8,000	172
156	A Simple Test for Casein in Milk and its Relation to the Dairy Industry	Hart	40,000	22
157	Licensed Commercial Feeding Stuffs, 1907	Woll and Olson	18,000	54
158	The Grade Stallion Situation in Wisconsin	Alexander	50,000	35
159	The Cranberry Insects in Wisconsin	Hardenberg	2,000	23
160	Tests of Dairy Cows, 1906–7	Woll and Harris	18,000	39
161	Grains and Forage Crops for Northern Wisconsin	Moore and Delwiche	10,000	23
162	Rusty Cans and Their Effect upon Milk for Cheesemaking	Olson	30,000	12
163	Licensed Commercial Fertilizers, with List of Licensed Feeding Stuffs, 1908.	Woll and Olson	18,000	31
	In addition to the above publications in the regular series, two special bulletins on the following topics have been prepared. These were especially designed for distribution at the Farmers' Institutes this last year, as these subjects were given especial consideration at most of these meetings.			
	Tuberculosis of Domestic Stock and its control	Russell	60,000	6
	The Seeding, Growing, and Curing of Alfalfa	Moore	60,000	12

A brief summary of the bulletins of the regular series is herewith presented.

BULLETIN 153. PORTABLE HOG HOUSES.—This bulletin contains plans and specifications for the construction of portable hog houses of the small and the large types. The designs are such as can be followed by most farmers, involving only simple methods of construction with materials that are readily available. These suggestions are based upon experiences with such hog houses on the University farm and at other places. The advantages of the portable house mentioned are: it is cheap and easily built; can be readily moved; is adapted to the needs of the general farmer and the breeder of pure-bred stock; and is the most natural and sanitary system of housing swine. The styles illustrated and described are the A-shaped portable house,

the small shed roof house, the large shed roof house, and the large central hog house.

BULLETIN 154. A CREAMERY METHOD FOR THE DETERMINATION OF WATER IN BUTTER.—Last year the Dairy Department perfected a simple factory method for the determination of the amount of moisture in butter. This question has assumed especial importance since the passage of the national pure food law, which construes butter adulterated, and therefore taxable when it contains more than 16 per cent of water. This bulletin gives instructions relative to sampling and the best methods of weighing. The newly devised Wisconsin high pressure oven is described, and full directions given for its use. This process enables the operator to determine accurately the water content of butter, thereby rendering his product more uniform under such control.

BULLETIN 155. THE DISTRIBUTION OF STALLIONS IN WISCONSIN.—This bulletin includes a summary of the progress of work done by the Department of Horse Breeding since the enactment of the stallion law in 1905. The strong and weak points of the law are pointed out and the needs of new legislation emphasized. Questions concerning the renewal of licenses, number, and character of same are given, together with a discussion of the relation of soundness to the law. The full text of the Wisconsin stallion law with amendments and additions is presented, as well as a brief statement of stallion legislation in other states. The number and breed of stallions is given by counties and the directory of owners of stallions licensed in 1906 is reprinted from Bulletin 141.

BULLETIN 156. A SIMPLE TEST FOR CASEIN IN MILK AND ITS RELATION TO THE DAIRY INDUSTRY.—This bulletin, announcing the new simple casein test, gives full directions concerning its manipulation, and discusses its relation to the dairy industry. The test involves the use of a special tube, so designed as to permit of the reading of the percentage of casein directly after it has been precipitated by dilute acetic acid and the fat removed with chloroform. A special centrifuge is used to mass the casein into one part of the tube for reading. The bulletin also gives a discussion of the accuracy of the test and conditions influencing it, as well as some precautions to be observed. The method can be followed by an unskilled operator with reasonable accuracy when proper care is exercised. This discovery

is not only of value to the factory operator, but places in the hands of breeders an instrument which may result in the selection and development of high casein producing animals.

BULLETIN 157. LICENSED COMMERCIAL FEEDING STUFFS, 1907.—This bulletin presents a list of manufacturers' names with licensed brands and the guarantees of protein and fat of each brand as given by the manufacturers as required by law. An analysis of various brands is also presented, as well as the law relating to the control of feeding stuffs.

BULLETIN 158. THE GRADE STALLION SITUATION IN WISCONSIN.—The beneficial effects of the licensing of public service stallions are fully outlined in this popular discussion of the subject. The prevalence of the grade stallion, predominance of certain breeds, and some notes upon poor practices among farmers are given. The stallion situation of other states and abroad is noted, and improvements in the system of offering premiums for stallions at county fairs are suggested. The bulletin furnishes an excellent popular discussion of the situation disclosed by the license operations of the Department of Horse Breeding.

BULLETIN 159. THE CRANBERRY INSECTS OF WISCONSIN.—This bulletin contains a summary of studies of the problems of insect control on cranberries for two seasons in Wisconsin. The peculiar soil and vegetation conditions of this state make special investigations necessary, and Wisconsin cranberry growers cannot rely upon results of work done in other states along this line. Detailed descriptions of the cranberry insects, together with colored plates, make this bulletin especially valuable for those desiring to become familiar with enemies of the cranberry in Wisconsin.

BULLETIN 160. TESTS OF DAIRY COWS, 1906–1907.—A summary of tests conducted and cows tested is presented with all of the test records and illustrations of some of the best producers. Special attention is given to the record of Colantha 4th's Johanna, the champion Wisconsin cow, and the test conducted on her.

BULLETIN 161. GRAINS AND FORAGE CROPS FOR NORTHERN WISCONSIN.—This bulletin contains discussions and recommendations based upon results with crops grown during the past two years at the Northern Sub-station farms, together with notes on other crops suited to the northern part of the state. Trials with barley, corn, oats, field peas, wheat, alfalfa, soy

beans, and root crops are outlined. Notes on varieties giving best results are of special value.

BULLETIN 162. RUSTY CANS AND THEIR EFFECT UPON MILK FOR CHEESEMAKING.—This bulletin outlines experiments on the influence or rusty utensils on rennet action in milk, and gives the effects of handling milk for cheesemaking in poor utensils. Attention is called to the methods followed in European dairy countries as compared with conditions in this country as regards the type and construction of milk vessels. The need of a better grade of utensils and better care of the same is duly emphasized.

BULLETIN 163. LICENSED COMMERCIAL FERTILIZERS, WITH LIST OF LICENSED FEEDING STUFFS, 1908.—This bulletin is published in accordance with the requirements of the state law on commercial fertilizers and feeding stuffs, and gives results of analyses of samples. Some suggestions as to the purchase and use of commercial fertilizers and the valuation of the same are included to aid the farmer. The names of firms who have registered feeds for license in this state, together with a list of brands, are given.

EXTENSION SERVICE.

The function of the modern agricultural college is preeminently that of an instrument of the state to aid in all possible ways in the development of the commonwealth. The strength of such an institution lies in its close touch with the people, and whenever it loses the stimulus that comes from this relationship, its value will begin to lessen. A constantly increasing amount of aid has been afforded the agricultural interests for years by carrying the results of scientific studies *directly* to the farmer. This work is appreciated in a way that places the obligation of its continuance and development upon us, and the time is now ripe for the organization of our extension activities into more definite and correlated lines.

Naturally this extension work may take concrete form by the way of college or station extension, but it is very difficult to separate these two lines, as the work is essentially showing the farmer how to apply directly to his problems the results gathered in experimental inquiry.

During this last year special effort has been made to help the

state-at-large by holding farmers' courses of several days' duration, similar to the ten day Farmer's course, which has been in progress at the University for the last five years. The course at Madison continues to grow in influence. Last year over 700 farmers, from 50 counties and 4 outside states, participated in this work. More and more it is attracting the most progressive men of the state, and its influence is probably greater than any other line of our work for the time, energy, and expense involved. We find that this brief course is a prominent feeder of our regular courses of study, as the farmer thereby becomes convinced of the desirability of an agricultural course for his boys.

In addition to this course, two courses were held in cooperation with the County Agricultural Schools at Winneconne and Marinette. A staff of a half dozen or more teachers from the Agricultural College gave a series of lectures, demonstrations, and judging work that was most enthusiastically received. From 400 to 600 persons, from 9 different counties, were in attendance at Winneconne. This work in a way may be regarded as partially equivalent to the Farmers' Course at Madison in bringing the University into direct relation with many people who are unable to attend the regular winter course at Madison. The coming year this series of meetings will be extended so as to include all of the County Agricultural Schools that are now organized. This extension work, is planned in connection with the Farmers' Institutes, so that a wider field is covered than was formerly possible.

LECTURES, CORRESPONDENCE, ETC.—Members of the College staff have held meetings or assisted in such work by giving lectures in over 80 cases during the last year. The demand for such aid is many times our ability to supply.

A continually increasing amount of correspondence relating to what is substantially extension work is carried on each year. An approximate estimate for the past year indicates the transmission of about 30,000 letters, besides the mailing of 360,000 bulletins and reports.

DEMONSTRATION WORK.

While much good can doubtless be done by extension lectures. separately or in a series, the nature of the problems attacked is often such that an actual demonstration is the most effective

way to the present the subject. The eye is the quickest road to the brain, and actual demonstration of a process will often convince where all other means fail. Past experience has proven the value of this demonstration work. The following summary gives a digest of the more important lines in progress during the past year.

POTATO SPRAYING.—The losses from potato blight vary greatly from year to year (10 to 70 per cent actually recorded), but have been severe for three years out of the last four. Proper application of Bordeaux mixture would reduce this loss one-half, and for the last four seasons the Horticultural department has carried on demonstration spraying work on 200 acres in seven counties in the potato belt (Waupaca, Waushara, Dunn, Columbia, Portage, Sauk, and Burnett). Field meetings, held at the time of application of the spray, and again at harvest time, gave opportunity to demonstrate the manner of compounding the mixture, as well as the results obtained. The Station furnishes the machines (loaned to us by the manufacturers), the spraying materials, and supervises the work. The farmer furnishes the necessary labor for compounding and applying the mixture, and takes care of the crop. From 30 to 60 bushels increase per acre has been obtained, and it is noteworthy that practically the only portions of the state where commercial spraying is practiced are those in the vicinity of these demonstration fields.

The potato industry of this state is susceptible of wide expansion on the sandy loams of central and northwestern Wisconsin, and it is of utmost importance to induce the growers to spray. This demonstration work should also be coupled with recommendations as to improved methods of culture and seed selection.

ORCHARD SPRAYING.—This year demonstration work was extended to orchard fruits. Three orchards in Sauk, Richland, and Winnebago counties, have been sprayed with Bordeaux mixture for apple scab, and arsenate of lead and Paris green for codling moth and leaf-eating insects. This work has been supervised by Mr. Milward, the field expert on potatoes, as most of the orchard spraying requires treatment from early spring to mid-summer, while the potato work runs from June to October. The results of the work will soon be summarized.

TRIAL ORCHARDS.—In connection with the work of the northern sub-stations, trial orchards have been established at Superior, on the Bayfield Peninsula, and on Madeline Island, in Lake Superior. From indications it appears that this section of the state has many advantages as a fruit growing region.

TUBERCULOSIS POST-MORTEM DEMONSTRATIONS. — The campaign against bovine tuberculosis has been aggressively pushed this year by continuing the method of holding public demonstrations (in cooperation with the State Live Stock Sanitary Board), where reacting cattle are killed and the nature of this cattle scourge demonstrated to stock owners. The widespread interest thus developed has resulted in wholesale testing, and in some counties from 20 to 50 per cent of all dairy stock has now been examined.

Prior to the inauguration of this work, the Station was securing less than a thousand tests per year. This active demonstration campaign was begun in 1906, and the number of Station-controlled tests in that year increased to 5,000; in 1907 to 11,000, and last winter to nearly 30,000. The correspondence work connected with this has required the entire time of Mr. Hoffmann and two stenographers during the testing season. The reduction in tuberculosis noted is very marked, and the state is now actively reaping the benefits of its precautionary efforts, in that its reputation for healthy breeding and dairy stock is the best in the Union.

During the summer of 1908 a tuberculosis conference was held at Madison, attended by representatives of the live stock and veterinary interests of the upper Mississippi Valley states, at which consideration was given the securing of uniform methods of inspection and control.

NORTHERN SUB-STATIONS.—At three points in northern Wisconsin, Ashland, Superior, and Iron River, sub-stations have been established for several years, the object of which was to work out on the peculiar types of soil characteristic of the region, the best type of agriculture. At Ashland and Superior, this work is being done on the heavy red clays; at Iron River on the light sandy soil. These stations partake of the nature of demonstration farms, although much experimental work of value has been carried out on them. The work has been handled jointly by the departments of Soils, Agronomy, and Horticulture, and has been under the immediate management of Supt.

E. J. Delwiche. The results already attained are exceedingly satisfactory. Although in operation for only three years, they have profoundly affected the agricultural development of the region. Over 200 farmers have been assisted in carrying on cooperative tests with seed grains and forage plants.

The problems here under consideration are peculiarly difficult on the heavy red clays, as this type of soil is one with which most people are unfamiliar, therefore the experimental work on tile drainage, to remove the excess water, has been watched with especial interest.

The work in horticulture is also especially promising, as it seems quite likely that the Apostle Islands and the Bayfield Peninsula, are well adapted for the raising of orchard fruits. Small fruits of all kinds can be grown very successfully in these northern counties, and the exceptionally favorable markets that obtain at the head of the lakes, make this a very desirable line of agricultural development.

As indicating the appreciation with which the work of these northern sub-stations is held by the people in these regions, I append an extract from a letter received recently from a prominent business man of Ashland.

"I feel that your department of the University and in particular the experimental station deserves praise for instituting this station in this part of the state where it has long been urgently needed." * * *

"Many people who come up here to start homes for themselves are from the overcrowded cities and to this class of settlers especially the experimental farm here has proven to be of untold value. * * * We who are connected with the development of this part of the state appreciate very much the work that has been done on this experiment farm for its influence is wide-spread and by maintaining the work and increasing it in every way money would be wisely invested by the state."

GENERAL EXTENSION WORK.

DISSEMINATION OF PURE-BRED SEEDS.—The propagation and dissemination of pure-bred seed grains have been assiduously continued by the Agronomy Department. Members of the Experiment Association have aided greatly in this work, and Professor Moore estimates this year that one-fourth of the oats now grown in the state is of the Swedish Select type, one-third

of the barley is of the Oderbrucker or Manshury varieties, and about one-third of the corn now grown is from pure-bred seed. Over a thousand corn centers have been established this year where growers are propagating selected seed secured from the Station. This work has been pushed not only with reference to corn, but also with the smaller grains, and it is confidently expected within a comparatively short time that selected pure-bred varieties will take the place of the mixtures of varieties that are now used for seed purposes. In the matter of barley alone, this is a matter of the greatest import, as the value of the crop for certain special purposes, such as brewing, depends in a large measure upon its uniformity, and brewers are glad to pay a considerable advance over the market price of the grain to secure a type that is absolutely uniform in germinating quality.

SELECTION OF TOBACCO SEED.—For the last four years special effort has been given to the improvement of tobacco by seed selection. When this work was begun, there was found to be the greatest diversity in the character of the tobacco grown in the state. Each farmer raised his own seed by leaving a few stalks in the field to ripen. Starting with the best types that could be secured (Connecticut-Havana), Professor Sandsten has grown these under special conditions in different portions of the state for the last three years. Only typical plants have been allowed to mature, and in this period over 2,000 growers have received this improved seed, which is superior in quality, yields well, and the value of which is attested by the fact that at the meeting of the State Tobacco Growers' Association, this improved stock took the sweepstakes, first and second prizes. Professor Sandsten estimates at the present time that two-thirds of the Wisconsin crop is now produced from this selected seed.

YOUNG PEOPLES' CORN GROWING CONTESTS.—For the last few years Professor Moore has carried on a new type of extension work in connection with several of the county fair associations. Through the Secretaries of such associations, selected types of corn have been distributed free to young people, and full directions given to them as to method of handling and harvesting the crop. Exhibits were then made at the county fairs in the fall, and through the stimulus of special premiums given by the fair authorities, as well as by the general public, interest of the young people was aroused and maintained. Dur-

ing this last year the work has been extended, and 26 county fairs have cooperated in this dissemination work on corn alone. At the Dane County fair this fall, over 800 corn exhibits, grown by the young people of the county, were on display. A larger number of exhibits of corn was made in this single year than in the previous history of the Association. At the Chippewa Falls fair, approximately 600 exhibits were also secured.

This work has greatly stimulated the interest of young people in farm matters, and offers a sane way to attack the problem of interesting the youth in agricultural education. In a number of counties school superintendents have aided greatly in this work, thus bringing the rural schools in direct relation with this extension work of the University.

COOPERATIVE LIVE STOCK BREEDING ASSOCIATIONS.—A most important move in securing an improved quality of live stock is to induce the farmers to purchase pure-bred sires. Special effort has been directed by Professors Humphrey, Alexander, and Fuller, toward the organization of cooperative breeding organizations, by aiding the farmers of a community to unite along some special line of breeding. The success which has been attained by such community effort is most striking. Jefferson County last year sold $600,000 worth of dairy stock; Lake Mills is now the leading Holstein center of America, $175,000 worth of stock having been sold last season to all parts of the world, much of it going to Mexico, Japan, and South America. The matter of organizing these associations has been pushed, with the result that sixteen have been formed for the breeding of dairy cattle, one for draft horses, and one for swine, the most of them within the last two or three years. This work is rapidly making Wisconsin the leading breeding state for dairy cattle.

DAIRY COW TESTS.—The extension work in testing officially the milk production of pure-bred dairy stock continues to increase year by year, under Professor Woll's direction, this year, the total number of tests conducted of all kinds and breeds being 1,290 on 421 cows. At present 12 supervisors are employed under Civil Service rules, the breeders whose cows are tested paying the expenses connected with the same. The most phenomenal record noted is that of the banner milk-producing cow, Colantha 4th's Johanna, owned by W. J. Gillett of Rosendale, which produced in one year nearly 27,500 pounds of milk, or

approximately 18 times her own weight. This is the highest authenticated record of any dairy animal, and her official test created world wide attention when published.

There is much need that the farmers interested in general dairying take up the work of testing their cows to ascertain whether or not they are profitable. This work can be better accomplished by the organization of cow testing associations. As this line of extension effort is being pushed at the present time by the Wisconsin Dairymen's Association, there is not the necessity for the College developing the same, but the need of such work is yet very great throughout many portions of the state.

BUTTER AND CHEESE SCORING EXHIBITIONS.—These are designed to help the factory operator by scoring his product and advising him how to improve the quality of the same. The work is yet new, this being the first full year, but 1,400 samples of butter, from 254 exhibitors, and 778 samples of cheese, from 195 makers, have been examined by a board of judges and reported upon by Mr. Michels. Of these, 150 exhibitors have sent in monthly samples at least six or more times. It is noteworthy that the scores of those who are continual exhibitors in this work are materially higher than the average, and the participants in the scoring exhibitions were the prize winners at the State Fair in 1907 and 1908, and at the dairy conventions, both state and national.

It would be highly desirable if it were possible for us to send a field instructor to the various factories to aid the maker when troubles of a more or less serious character are discovered. A special attempt in these exhibitions should be made to reach the maker whose product is not first class, and, as is usual where scoring is carried on, the emphasis falls on the man who makes the best record.

DRAINAGE SERVICE.—The demand for aid in formulating plans for the reclamation of wet lands by tile drainage is rapidly developing. The Soils Department aided last year about 150 land owners by correspondence, 35 individual owners, and 17 drainage districts. A considerable part of Mr. Jones' time was employed in examining locations and making plans for installation of tile drainage.

SOIL EXAMINATIONS.—There is also much call for help in the matter of soil management, particularly as to special types, as the marshy, sandy, and heavy clay soils. Special aid has been

given by the Soils Department in about 400 cases in the last two years. Seven cooperative fertilizer experiments on peat soil, with potash and phosphorus, were under consideration this past season. Extension work along these lines would require the entire time of a soil expert, if we were in position to furnish the same.

SOIL SURVEY.—As these calls for help in the matter of soil management increase, it becomes more and more evident that there must be made as soon as possible a suitable soil survey. The Geological and Natural History Survey have done some work in this connection, but the work naturally has not been directed with especial reference to agricultural conditions. Recognizing the desirability of cooperating with this organization, the Soils Department has this year carried out some preliminary work on such a survey in Pierce, Eau Claire, Chippewa, and Rusk counties. Great interest has been manifested in the work by the farmers in these regions, and the methods developed will indicate the course to follow in further study. It is hoped that arrangements may be made at the coming meeting of the legislature to provide for the establishment of such a survey.

INSPECTION AND CONTROL WORK.

In several departments of the state's activities, the police and inspection work required by law is placed under the auspices of the Experiment Station, rather than under special, separate boards. Inasmuch as this is for the protection of the farmer, and thus for the state-at-large, it is here grouped in connection with the extension service, rather than under the head of research work. It is highly important that this inspection work be aggressively prosecuted, as it is only in this way that the consuming public can be thoroughly protected against fraud and deception.

STALLION LICENSING.—The attempt to improve the horse industry of the state by licensing stallions has been attended with much success. The first census, taken in 1905, revealed the fact that of the 3,000 animals used for service, 60 per cent were of grade or "scrub" origin. The law has only been in operation three years, but a noticeable diminution in grades is already observed. Dr. Alexander, under whose direction this work has been developed, reports that over 550 animals have been re-

tired from service, of which nearly 100 were castrated, or licenses revoked for unsoundness. Several flagrant violations of the law have been found. Fraudulent registry papers have been disclosed, and cases determined where purchasers have been actually defrauded by falsification of records.

This important work of improving the horse industry needs further development, as it is a peculiar fact that less attention is paid to the mating of horses than cattle. The good example set by Wisconsin in the matter of licensing stallions was quickly appreciated by other states, as similar laws have since been enacted in five other states.

The following financial statement gives the receipts and disbursements of the Department of Horse Breeding for the year June 30, 1907 to June 30, 1908, inclusive.

To Fees, original license certificates	$1,117 47	
renewals	1,782 30	
transfers	119 15	
duplicates	75 00	
By Salaries		$2,164 24
Office and traveling expenses		527 10
Balance		402 58
	$3,093 92	$3,093 92

FEED AND FERTILIZER INSPECTION.—The work in this department under the direction of Professor Woll has increased very much during the last year, due to the amendment of the state feeding stuffs law, whereby all mill feeds are made subject to a manufacturer's annual license. Some 840 feed stores in 217 different towns have been licensed, and 411 samples of feeding stuffs collected and analyzed during the year.

The new feeding stuffs law has been enforced this year under protest of the millers, and a suit has been brought to test its constitutionality in the courts. The law was sustained in the lower court, and is now before the Supreme Court.

The necessity for a strict control in this work is recognized from the several important cases of adulteration and fraud that have been discovered this year. Cases of gross contamination of mill feeds with foul weed seeds and mill sweepings, and of cotton-seed hulls in molasses feed, have been discovered. The beneficial effect of state control is noted, however, in the greatly improved character of feeds now sold in the state, as compared with those which were previously handled.

A most flagrant violation of the fertilizer law was found in the case of one manufacturer who put powdered quicklime on

the market and sold it at the rate of $70 to $150 per ton, according to size of package.

NURSERY INSPECTION.—Over a hundred nurseries have been inspected this year by the representatives of the Horticultural Department, under whose jurisdiction this work is placed. Again the San José scale has been found in nursery stock, and also in a cemetery in Milwaukee, where infested trees from outside of the state were shipped in. For three years this disease has now been found in nursery stock, but so far it has been held in check. It is very desirable that the law be modified so as to control interstate shipments. As it now stands inspection of our own nurseries is made, but no sort of adequate control is exercised over shipments from outside the state.

SEED CONTROL.—The Agronomy and Horticulture Departments for a number of years have made numerous tests of seeds, grains, and forage plants, as to purity, germination, etc. The importance of this work is coming to be recognized more and more, as it becomes evident that the yield of grains and forage crops is so largely influenced by the character of the seed sown. This last year over 500 samples of seeds were tested by the Agronomy Department, and 75 by the Horticultural Department, among which a number were found to be so badly adulterated and contaminated with noxious weed seeds, that their introduction would have been a serious menace. The whole matter of seed control should receive early attention, and a satisfactory statute drawn which will put this matter upon a proper foundation, so that the farmer can be protected from noxious weeds and adulterations that are now very frequent.

ACKNOWLEDGMENTS.

The following donations and loans have been received by the Agricultural Experiment Station during the past year.

DONATIONS.

Farmers' Phosphate Co., Urbana, Ill., four tons rock phosphate.
German Kali Works, New York, N. Y., two tons sulphate of potash.
Nitrate of Soda Propaganda, New York, N. Y., 200 pounds of nitrate of soda.
Parke. Davis & Co., Detroit, Mich., pure cultures of bacteria.
J. Reichel, Veterinary School, University of Pennsylvania, pure cultures of bacteria.
J. S. Biesecker, 99 Murray St., New York, N. Y. sanitary milk pail.
Ekenberg Milk Products Co., Cortland, N. Y., five pounds of powdered milk.
New York State College of Agriculture, Ithaca, N. Y., pure cultures of bacteria.
Earp-Thomas Farmogerm Company, Bloomfield, N. J., samples of Farmogerm.
The Good Health Co., Battle Creek, Mich., Yogurt tablets.
United States Sugar Company, Madison, Wis., eight pounds sugar beet seed from Seattle, fifteen pounds seed grown at Nordhausen, Germany.
Garton Brothers, Acton Grange, Warrington, England, one-half bushel each of six varieties of oats. and one of barley, also eight pounds sample of barley and four ounce package of oats.
Salzer Seed Co., La Crosse, Wis., one peck Regenerated Bonanza oats, one peck Black Egyptian oats, five pounds National oats, five pounds Emperor William oats, five pounds Great Northern oats, five pounds Black Prolific oats.
Andrew Finsnes, Chippewa Falls, Wis., forty ears Clark's Yellow dent corn.
William Nesbit, Richland Center. one peck Scotch oats.
Llewellyn Fleek, Brodhead, three ears White dent corn.
W. S. Marshall, Delton, three ears Salamander corn grown in Texas.
Joshua Strange, Marion, Ind., two corn racks.
C. A. Stannard, Emporia, Kan., one barrel of swine dip.
J. H. McMullan, Woodstock. Ohio, two Rambouillet wether lambs.
Renk Bros., Sun Prairie, Wis., two Shropshire wether lambs.
A. H. Ried, Philadelphia, Pa., pasteurizer and cooler.
Parke-Davis Laboratory, Detroit, Mich., culture for starter
Elov Ericcson, St. Paul. Minn., culture for starter.
Chrs. Hansen Laboratory, Little Falls, N. Y., culture for starter.
S. C. Keith, Boston, Mass., culture for starter.
Marschall Dairy Laboratory, Madison, Wis., two sets apparatus for determining acidity of whey.
J. Frank Smith, Pleasanton, Kan.. copy "Eby Handy Tables."
J. I. Case Thresher Co., Racine, Wis., 150 copies Traction Engine Manual.
De Laval Separator Co., Chicago, Ill., two sets tread wheels, two rubber bowl rings.
Wells-Richardson Co., Burlington, Vt., one gallon butter color.

LOANS.

Creamery Package Manufacturing Co., Chicago, Ill., No. 2 Twentieth Century milk heater, Farrington pasteurizer, Farrington cream ripener, Boyd cream ripener, Victor starter can, 300 gallon Wizard cream ripener, two Wizard testers, 24 bottle turbine, two Victor foot powers, Ideal skim milk weigher, 12-bottle hand tester, two 24-bottle turbine testers, two Wisconsin curd tests. No. 1 Twentieth Century heater, American butter printer, Disbrow churn, Turbine tester, 24 bottle, Hand tester, 12 bottle, Hand tester, 8 bottle. Victor skim milk pasteurizer, 24-bottle tester for electric motor. Trunion starter can, moisture oven, casein tester, 6-bottle. Farrington Jr. moisture oven.

A. H. Barber Creamery Co., Chicago, Ill., No. 4 power cream separator, No. 6 Simplex churn, No. 2 B. & W. milk heater, No. 1 Simplex hand separator, B. & W. check pump.

D. H. Burrell Co., Little Falls, N. Y., 4-bottle hand tester, 36-bottle turbine tester, 6-bottle facile tester, 24-bottle hand tester, 24-bottle turbine tester, Simplex separator bowl, No. 4.

International Harvester Co., Madison, Wis., No. 2 A Cream Harvester separator, No. 4 Dairy Maid separator, 3 H. P. upright gasoline engine, Dairy Maid separator, Blue Bell separator.

Perfection Anti Dirt Pail Co., Albert Lea, Minn., milk pail.

Melchior Armstrong & Dessau, New York, N. Y., Perfect Gloria separator.

J. Cherry, Cedar Rapids, Iowa, Edwards Mother Culture case with bottle.

Exhaust Steam Purifier Co., Berlin, Wis., Purifier pump and tank.

Montgomery Ward & Co., Chicago, Ill., Golden Cream Harvester.

G. W. Kennedy, Thornton, Iowa, Kennedy aerator.

Marshfield Churn Co., Marshfield, Wis., hand churn.

Marschall Dairy Laboratory, Madison, Wis., two Marschall acid tests.

Milo D. Beach, Litchfield, Conn., Triumph test bottle shaker.

Fuller & Johnson Co., Madison, Wis., 3½ H. P. gasoline engine, 2½ H. P gasoline engine.

National Separator Co., Goshen, Ind., one hand separator.

Burmeister & Wain. Copenhagen, Denmark, Perfect hand separator.

Smith Manufacturing Co., Chicago, Ill., Great Western cream separator.

Miller-Tyson Co., Canton, Ohio, milk heater.

Brillion Iron Works, Brillion, Wis., Junker curd mill.

Albrecht Manufacturing Co., Kewaunee, Wis., skim milk and whey pump.

Perfection Churn Co.. Owatonna, Minn., Size 4 power churn.

National Wrapping Machine Co., Los Angeles, Cal., butter wrapping machine.

Standard Separator Co., Milwaukee, Wis., two hand separators, Champion No. 4 and No. 6.

Sears, Roebuck & Co., Chicago, Economy cream separator.

Lever Cream Separator Co., Indianapolis, Ind.. hand separator.

Northern Electric Co., Madison, Wis., 5 H. P. motor.

King & Walker Co., Madison, Wis., high pressure moisture oven.

Standard Separator Co., Milwaukee, Wis., Champion No. 6 and No. 4 cream separators.

Currie Hardware Co., Mason City. Iowa, two Eclipse moisture ovens.

Gehl Mfg. Co., Milwaukee, Wis., butter printer.

International Construction Co., Chicago, Ill., 6-bottle filler.

Jansen Mfg. Co., Topeka, Kan., pasteurizer and cooler, Haughdahl starter can.

Vermont Farm Machine Co., Bellows Falls. Vt., 20-bottle turbine tester, No. 2½ U. S. separator, 12-bottle hand tester, No. 7 cream separator, 24-bottle Agos tester, No. 6 hand separator, No. 8 hand separator.

De Laval Separator Co., Chicago, Ill., Acme cream separator, Nos. 17, 12 and 15 hant separators, Sectional hand separator.

McKinnon & Co., Sheboygan Falls Wis., Combination cheese press.

Empire Separator Co., Bloomfield, N. Y., Nos. 1 A and 2 B cream separators.

Sharples Separator Co., West Chester, Pa., 12-bottle Russian tester, Triumph test bottle shaker, No. 32 power separator with accelerator washer, Nos. 6 and 4 hand separators.

Acme Harvester Co., Poria, Ill., 6-ft. grain binder.

American Plow Co., Madison, Wis., 16-inch sulky plow, disc harrow and transport truck.

Alamo Mfg. Co., Hillsdale, Mich., 18 H. P. gasoline engine.

J. D. Adams Co., Indianapolis, Ind., Road King road grader.

Baker Mfg. Co., Evansville, Wis., 4-horse power vertical gasoline engine.

Aspinwall Mfg. Co., Jackson, Mich., potato planter and cutter.

Bateman Mfg. Co., Grenlock, N. J., potato planter.

Bradley Mfg. Co., Bradley, Ill., corn planter and exhibition platform.

Bruley Steel Fence Post Co., Milwaukee, Wis., six indestructible fence posts, two rods of woven wire.

F. H. Battles, Rochester, N. Y., two swinging cow stanchions.

J. I. Case Plow Co., Racine, Wis., corn planter and exhibition platform, disc harrow.

Champion Potato Machinery Co., Hammond. Ind., potato planter and cutter.

W. B. Crumb, Forestville, Conn., two swinging cow stanchions.

J. R. Christensen, Oshkosh, Wis., brick silo model.

Dain Mfg. Co., Ottumwa, Ia., hay loader and mower.

Deere, Mansur, & Co.. Moline, Ill., corn planter and exhibition platform and one exhibition corn planter shank.

John Deere Plow Co., Moline, Ill., Deere 16-inch sulky plow, Elk corn cultivator, and Deere corn cultivator.

Jos. Dick Agricultural Works, Canton, O., Blizzard silage cutter.

Emerson Mfg. Co., Rockford, Ill. No. 10 corn planter, 14-inch mold board gang plow, No. 5 standard mower.

Fuller and Johnson Mfg. Co., Madison, Wis., corn planter, gang plow, disc harrow, cultivator, 6 H. P. open jacket gasoline engine, walking plow, 5 tooth walking cultivator. transplanter.

Gilson Mfg. Co., Port Washington, Wis., 1 H. P. air cooled gasoline engine.

Hayes Pump and Planter Co., Galva, Ill., corn planter.

Hunt, Helm, Ferris Co., Harvard, Ill., swinging cow stanchions.

Johnson Field Mfg. Co., Racine. Wis., grain cleaning mill.

Independent Harvester Co., Plano, Ill., manure spreader.

International Harvester Co., Chicago, Ill., 12 H. P. portable gasoline engine, 3 H. P. vertical gasoline engine, 2 H. P. sectional gasoline engine, mounted exhibit. farm wagon and manure spreader, 3-roll corn shredder, 6-foot Deering grain binder, 6-foot Champion binder, 6-foot McCormick binder, one binder attachment and one four-row corn shredder, 6-foot Milwaukee grain binder, 6-foot Osborne grain binder.

Janesville Machine Co., Janesville, Wis., corn planter and exhibition platform.

J. I. Case Threshing Machine Co., Racine, Wis., 20 H. P. traction engine, 15 H. P. traction engine.

Advance Thresher Co.. Battle Creek, Mich., 16 H. P. engine.

Gaar-Scott Co., Richmond, Ind., 16 H. P. engine.

Louden Machine Co., Fairfield, Ia., four swinging cow stanchions.

Minneapolis Silo Co., Minneapolis, Minn., section of stave silo.

Manson Campbell Co., Detroit, Mich., Chatham fanning mill and corn grader.

MacDonald Bros.. Pleasant Hill, Mo., 4-ton wagon platform scale.

Mehring's Pneumatic Hand Power Milking Co., cow milker.

Meyers Bros., Ashland, O., pump exhibit, hay track carriers, and slings.

Northern Electric Mfg. Co., Madison, Wis., one 10 Kl. generator and one H. P. motor.

Newton Co., Batavia, Ill., Newton improved animal tie.

E. Prescott. Boston, Mass., two swinging cow stanchions.

Robert Rom Co., Milwaukee, Wis., No. 5 economical hot air engine.

Reliance Iron and Engine Co., Racine, Wis., 4½ H. P. gasoline engine.

O. H. Robertson, Forrestville, Conn., two swinging cow stanchions.

D. M. Sechler Carriage Co., Moline, Ill., Black Hawk corn planter and exhibition platform. and one corn planter shank.
Stowell Mfg. Co., Milwaukee, Wis., No. 3 hay carrier and 15 feet of steel track.
Simplicity Tank Heater Co., Sparta, Wis., Simplicity tank heater.
Smith Mfg. Co., Chicago, Ill., manure spreader and 2 H. P. gasoline engine.
Temple Pump Co., Chicago, Ill., 5 H. P. double cylinder kerosene burning engine.
Van Brunt Mfg. Co.. Horicon, Wis., 17 disc 6 inch drill, shoe and bar, and sample feed gate.
Wizard Plow Co., Batavia, N. Y., bean h[illegible]
Wood Automatic Corn Planter Co., Milwaukee, Wis., automatic planter attachment.
F. & J. H. Welcher, Newark, N. J., two swinging cow stanchions.
Egan Mfg. Co., La Crosse, Wis., sprayer.
Ayers Bros.. Honey Creek, Wis., Brown Swiss cow.
Charles L. Hill, Rosendale, Wis., Guernsey bull
Gay Stock Farm, Holstein bulls.
J. Q. Emery & Son, Edgerton, Wis., Guernsey bull.
Renk Bros., Sun Prairie, Wis., Hampshire ram.
Arthur Broughton, Albany, Wis.. Clydesdale stallion.
Pabst Stock Farm, Oconomowoc, Wis., Percheron stallion.

EXCHANGES.

The following papers come to the Station in exchange for its reports and bulletins. While used by those connected with the Station to learn the expression of agricultural experience and sentiment, they are placed in the library where they can be read and referred to by our agricultural students, and others of the University, as well as visitors.

FOREIGN EXCHANGES.

A Lavoura, Rio de Janeiro, Brazil.
L'Agricoltura Alessandrina, Alessandria, Italy.
L'Agricoltura Moderna. Milan, Italy.
Agricultural Bulletin, Straits Settlement, Singapore, East Indies.
Agricultural Gazette of New South Wales, Sidney, Australia.
Agricultural Journal of the Cape of Good Hope, Cape Town, South Africa.
Agricultural Journal of India, Calcutta.
Agricultural News, Bridgetown, Barbados, West Indies.
Boletim de Agricultura, Sao Paulo Brazil.
Boletim do Instituto Agronomico, Sao Paulo, Brazil.
Boletin del Ministerio de Agricultura, Buenos Aires, Argentina.
Bulletin de l'Agriculture, Brussels, Belgium.
Bulletin des Séances de la Société Nationale d'Agriculture de France Paris.
Bulletin of the College of Agriculture, Imperial University, Tokyo, Japan.
Bulletin of the Department of Agriculture, Kingston, Jamaica.
Chronique Agricole du Canton du Vaud. Lausanne, Switzerland.
Cold Storage and Ice Trades Review, London, Eng.
Extrait des Travaux de la Société Centrale d'Agriculture du Department de la Seine inferieure, Paris.
Farmer's Advocate, London, Ontario.
Farmer's Advocate, Winnipeg, Manitoba.
The Field, London, England.
Garden and Field, Adelaide, South Australia.
Irish Farming World, Dublin. Ireland.
Journal für Landwirtschaft, Berlin, Germany.
Journal of the Bath and West of England Society, Bath, England.
Journal of the Board of Agriculture, London, England.
Journal of the British Dairy Farmers' Association, London, England.

Journal of the Department of Agriculture of South Australia, Adelaide, Australia.
Journal of the Department of Agriculture of Victoria, Melbourne, Australia.
Journal of the Department of Agriculture of West Australia, Perth, Australia.
Journal of the Royal Agricultural Society, London, England.
Journal of the Royal Horticultural Society, London, England.
Journal of the Sapporo Agricultural College, Sapporo, Japan.
Kgl. Landtbruks-Akademiens Handlingar och Tidskrift, Stockholm, Sweden.
Landwirtschaftliches Wochenblatt f. Schleswig-Holstein, Kiel, Germany.
Live Stock Journal, London, England.
Milch Zeitung, Leipzig, Germany.
Mitteilungen der Deutschen Landwirtschafts-Gesellschaft, Berlin, Germany.
Natal Agricultural Journal, Maritzburg, Natal.
New Zealand Dairyman, Wellington, N. Z.
North British Agriculturist, Edinburgh, Scotland.
Nor'-West Farmer, Winnipeg, Manitoba.
O. A. C. Review, Guelph, Ontario.
O Criador Paulista, Sao Paulo, Brazil.
Queensland Agricultural Journal, Brisbane, Australia.
Revista Agricola, Sao Paulo, Brazil.
Rural World, London. England.
Tidsskrift for det Norske Landbrug, Christiania, Norway.
Tidsskrift for Landökonomi, Copenhagen, Denmark.
Transactions of the Highland and Agricultural Society of Scotland, Edinburg, Scotland.
Ugeskrift for Landmand, Copenhagen, Denmark.
Weekly Times, Melbourne, Australia.
West Indian Bulletin, Bridgetown. Barbados, West Indies.

DOMESTIC EXCHANGES.

Agricultural Experiments, Minneapolis, Minn.
Agricultural Student, Columbus, Ohio.
American Agriculturist, New York, N. Y.
American Cheesemaker, Grand Rapids, Mich.
American Cultivator, Boston, Mass.
American Farm World, Augusta. Me.
American Fertilizer, Philadelphia, Pa.
American Food Journal, Chicago, Ill.
American Fruit and Nut Journal, Petersburg, Va.
American Miller, Chicago, Ill.
American Poultry Advocate, Syracuse, N. Y.
American Sheep Breeder, Chicago, Ill.
American Sugar Industry and Beet Sugar Gazette, Chicago, Ill.
American Swineherd, Chicago, Ill.
American Thresherman, Madison, Wis.
Arboriculture, Connersville, Ind.
Arkansas Homestead, Little Rock.
Baker's Helper, Chicago, Ill.
Better Fruit. Hood River, Ore.
Breeder's Gazette, Chicago, Ill.
Bulletin of the National Association of Wool Manufacturers, Boston, Mass.
Chicago Daily Drovers' Journal, Chicago, Ill.
Chicago Dairy Produce, Chicago, Ill.
Chicago Live Stock World, Chicago, Ill.
Cold Storage, New York, N. Y.
Colman's Rural World. St. Louis, Mo.
Commercial Poultry, Chicago, Ill.
Cornell Countryman, Ithaca, N. Y.
Cotton Seed, Atlanta, Ga.
Creamery Journal, Waterloo, Iowa.
Dairy Record, St. Paul, Minn.
Dog Fancier, Battle Creek, Mich.
Elgin Dairy Report, Elgin, Ill.
Equity Farm Journal, Chicago, Ill.
Fancy Fruit, North Yakima, Wash.
Farm and Fireside, Chicago, Ill.
Farm and Stock, St. Joseph, Mo.
Farm Implement News, Chicago, Ill.
Farm Journal, Philadelphia, Pa.
Farm Life. Chicago, Ill.
Farm Machinery, St. Louis, Mo.
Farm, Stock and Home, Minneapolis, Minn.
Farmer, St. Paul, Minn.
Farmer and Breeder, Sioux City, Iowa.
Farmers' Guide, Huntington, Ind.
Farmers' Review, Chicago, Ill.
Farmers' Tribune, Sioux City, Iowa.
Farmers' Voice, Chicago, Ill.
Field and Farm, Denver, Colo.
Flour and Feed, Milwaukee, Wis.

Fruit Grower, St. Joseph, Mo.
Gas Power, St. Joe. Mich.
Gas Review, Madison, Wis.
Geflügel Züchter, Wausau, Wis.
Gleanings in Bee Culture, Medina, O.
Guernsey Herd Register and Breeders' Journal, Peterboro, N. H.
Hoard's Dairyman, Fort Atkinson, Wis.
Holstein-Friesian Register, Brattleboro. Vt.
Holstein-Friesian World, Ithaca, N. Y.
Homestead, Des Moines, Iowa.
Horse-Shoers' Journal, Detroit, Mich.
Horticulture, Boston, Mass.
Hospodar, Omaha, Neb.
Hospordårske Listy, Chicago Ill.
Illuminated World Life, Minneapolis, Minn.
Independent Farmer and Western Swine Breeder, Lincoln, Neb.
Indian School Journal, Chilocco, Okla.
Indiana Farmer, Indianapolis, Ind.
Industrious Hen, Knoxville, Tenn.
Iowa State Register and Farmer, Des Moines. Iowa.
Irrigation Age, Chicago, Ill.
Jersey Bulletin, Indianapolis, Ind.
Kansas Farmer, Topeka, Kan.
Kimball's Dairy Farmer, Waterloo, Iowa.
Lincoln Free Press, Lincoln, Neb.
Live Stock Journal, Chicago, Ill.
Louisiana Planter, New Orleans, La.
Metropolitan and Rural Home, New York, N. Y.
Michigan Farmer, Detroit, Mich.
Minnesota and Dakota Farmer, Brookings, S. Dak.
Minnesota Farm Review, St. Anthony Park, Minn.
Minnesota Horticulturist, Minneapolis, Minn.
Missouri Agricultural College Farmer, Columbia.
National Farmer, Winona. Minn.
National Farmer and Stock Grower, St. Louis, Mo.
National Monthly Farm Press, Chicago, Ill.
Nebraska Farmer, Omaha, Neb.
New York Produce Review and American Creamery, New York, N. Y.
North Dakota Magazine, Bismarck, N. Dak.
Northwest Horticulturist, Tacoma. Wash.
Northwestern Agriculturist, Minneapolis, Minn.
Nut Grower, Poulan, Ga.
Ohio Farmer, Cleveland, Ohio.
Oklahoma Agriculturist, El Reno, Okla.
Orange Judd Farmer, Chicago, Ill.
Oregon Agriculturist, Portland. Ore.
Our Horticultural Visitor, Kimmundy, Ill.
Pacific Dairy Review, San Francisco, Cal.
Pacific Fruit World, Los Angeles, Cal.
Pacific Rural Press, San Francisco, Cal.
Poultry, Peotone, Ill.
Poultry Husbandry, Waterville, N. Y.
Practical Farmer, Philadelphia, Penn.
Prairie Farmer, Chicago, Ill.
Profitable Poultry, Milton, Wis.
Pure Products, New York, N. Y.
Reliable Poultry Journal, Quincy, Ill.
Rocky Mountain Farming, Logan. Utah.
Shepherd's Criterion, Chicago, Ill.
Shepherd's Journal, Chicago, Ill.
Southern Fruit Grower, Chattanooga, Tenn.
Southern Planter, Richmond, Va.
Southwestern Farmer and Breeder, North Fort Worth, Texas.
Student Farmer, Madison. Wis.
Successful Farming, Des Moines, Iowa.
Successful Poultry Journal, Chicago, Ill.
Sugar Beet, Philadelphia, Pa.
Texas Farmer, Dallas, Tex.
Town and County Journal, San Francisco, Cal.
Trade, Baltimore. Md.
Thresherman's Review, St. Joe, Mich.
Twentieth Century Farmer, Omaha, Neb.
Wallace's Farmer, Des Moines, Iowa.
Wilson Bulletin, Oberlin, Ohio.
Wisconsin Agriculturist, Racine.
Wisconsin Equity News, Madison, Wis.
Wisconsin Farmer. Madison, Wis.
Wisconsin Sugar Beet, Menomonee Falls, Wis.

FINANCIAL STATEMENT.

The Wisconsin Agricultural Experiment Station, in account with the United States appropriations.

1907-1908.	Dr.	Cr.
To receipt from Treasurer of the United States as per appropriations for the year ending June 30, 1908, under the acts of Congress, approved March 2, 1887, and March 16, 1906.	$24,000 00	
By salaries,	....	$12,232 00
By labor,	....	3,735 16
By publications,	....	....
By postage and stationery,	....	228 50
By freight and express,	....	98 67
By heat, light and water,	....	81 00
By chemical supplies,	....	562 36
By seeds, plants, and sundry supplies,	....	1,592 77
By fertilizers,	....	35 79
By feeding stuffs,	....	2,082 68
By library,	....	595 29
By tools, implements and machinery	....	779 03
By furniture and fixtures,	....	65 00
By scientific apparatus,	....	543 71
By live stock,	....	191 51
By traveling expenses,	....	478 90
By contingent expenses,	....	15 00
By building and repairs,	....	682 63
	$24,000 00	$24,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Wisconsin Agricultural Experiment Station for the fiscal year ending June 30, 1908; that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $24,000, and the corresponding disbursements $24,000, for all of which proper vouchers are on file and have been by us examined and found correct.

And we further certify that the expenditures have been solely for the purpose set forth in the acts of Congress approved March 2, 1887, and March 16, 1906.

(Signed) MAGNUS SWENSON, *Chairman.*
L. S. HANKS,
PLINY NORCROSS,
Executive Committee.

ATTEST.
M. E. MCCAFFERY,
Custodian.

REPORT OF THE DIRECTOR

1909

REPORT OF THE DIRECTOR

H. L. RUSSELL

This year marks the beginning of a new quarter century of endeavor for the Wisconsin Agricultural Experiment Station since it was founded in 1883 by the state of Wisconsin before the passage of the Hatch Act by Congress, under which law most of the states began the agricultural experiment station movement. It would have been fitting to have recapitulated the results accomplished in this period of time, were it not for the fact that it has been customary to make such a review at decennial periods, and it does not seem wise to change this policy.

ADMINISTRATION

In detailing the work of the Station, it is difficult to separate it from the work of the College as a whole, for in the University of Wisconsin all lines of agricultural work have been so closely correlated within the limits of each department, that no sharp line of distinction can be drawn. Some stations have segregated their funds and their experimenting staff more or less completely from the teaching departments of the institution, but in Wisconsin development has not been in this direction. It has been the policy here to have each department, so far as possible, engage in both research and teaching, on the ground that the teacher was stronger for his contact with research work, and that the results of scientific investigation could only reach their highest fruition when given to others through the medium of teaching channels, either to the students at the College, or directly to the farmers throughout the state.

It must be admitted, however, in times of stress, when the teaching work increases with unusual rapidity, that the research work is likely to be the first to suffer, because the demands of the

students on the ground must naturally be met. But the value of Station work in Wisconsin has been sufficiently appreciated by the Regents so that it has been possible, in most cases, to adjust the relation of the two lines without permanent loss to the research work.

The staff of the College at the close of this fiscal year embraces 38 members, excluding administrative staff. The distribution of their work between teaching and Station research is as follows:

	Total number.	Mainly research.	Mainly teaching.	Both research and teaching.
Professors	20	7	3	10
Instructors	11	1	4	6
Assistants	7	4	1	2
	38	12	8	18

IMPROVEMENTS AND ADDITIONS TO RESOURCES

The work of every agricultural experiment station that is meeting the needs of its constituency is rapidly expanding as the problems pressing for solution become more numerous and complex; consequently, the institutions that are rising to the level of their opportunities are growing rapidly in resources as well as in scope of their work. It is fitting that reference be made here to the increased facilities which have been afforded this College as a whole during this past year.

STOCK PAVILION.—The most important addition in the last year is the completion of the Stock Pavilion. The College has long needed a large amphitheater in which demonstration exercises could be held before miscellaneous gatherings which assemble from time to time. The auditorium in Agricultural Hall, which has a seating capacity of 700, is excellently adapted to lecture and lantern demonstration purposes, but, naturally, cannot be used for demonstration work involving the actual use of animals, machinery, and the like. The work of the 10-days Farmer's Course, held each winter, has been much handicapped because no judging or demonstration pavilions were available which would satisfactorily accommodate more than 350 persons. This course has now become so popular that at some of the meetings last winter nearly 2,000 persons were in attendance at one time. While the College has recognized the need of improved facilities of this

sort, it has not felt that it could ask for the construction of a building for this purpose exclusively, unless the same could be built so as to permit it to be utilized more or less continuously.

The very rapid growth of the Long Course during the past year has necessitated larger accommodations for stock judging; consequently a building was planned that will serve the several purposes. The frontispiece of this report gives a view of the exterior of the new Stock Pavilion, while Figures 1 to 4 show

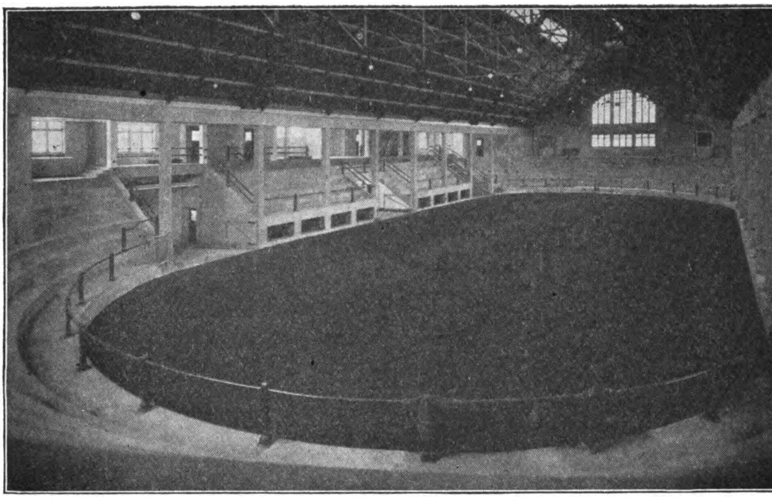
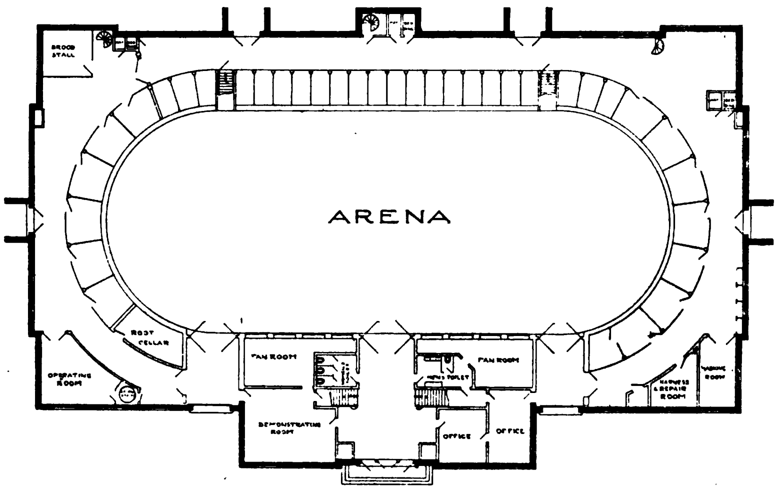


Figure 1. Arena of the live stock pavilion, which has seating capacity of 2,000 and curtain arrangement by which it may be divided into three rooms for classes in stock judging.

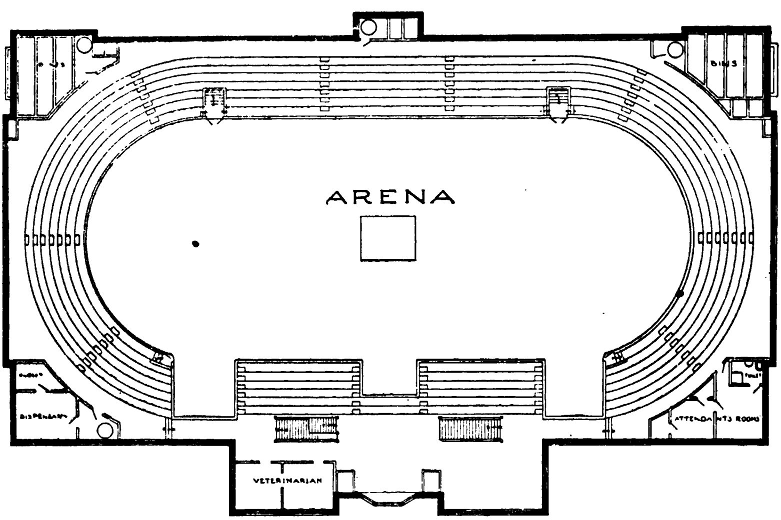
other views and a ground plan. The building is 115 feet by 212 feet, two stories and an attic in height, and covered with green enameled tile which gives a pleasing effect for such extensive roof surface.

The main arena is in the form of an ellipse 66 feet by 164 feet, which is large enough for all kinds of demonstration work, including the showing of horses, even for carriage work. Around the sides of the arena rise amphitheater seats of concrete, sufficient to accommodate 2,000 people. This large central space is so arranged that it can be divided into compartments with the aid of movable curtains, so that several classes may use these various compartments simultaneously. Beneath the amphitheater seats are 15 box stalls and 22 standing stalls for the use of horses belonging to the College and general University; also ample quar-



FIRST FLOOR PLAN

Figure 2. First floor plan of the live stock pavilion, showing stabling arrangements and offices.



SECOND FLOOR PLAN

Figure 3. Second floor plan of live stock pavilion, showing arena with concrete ledges for seats and additional offices.

ters for hospital purposes and care of sick animals. The building is to be furnished with modern veterinary conveniences for treatment and surgical operations, and a well equipped dispensary. Suites of offices for the farm superintendent and the Veterinary Division are provided, as well as a class room for lecture and demonstration work.

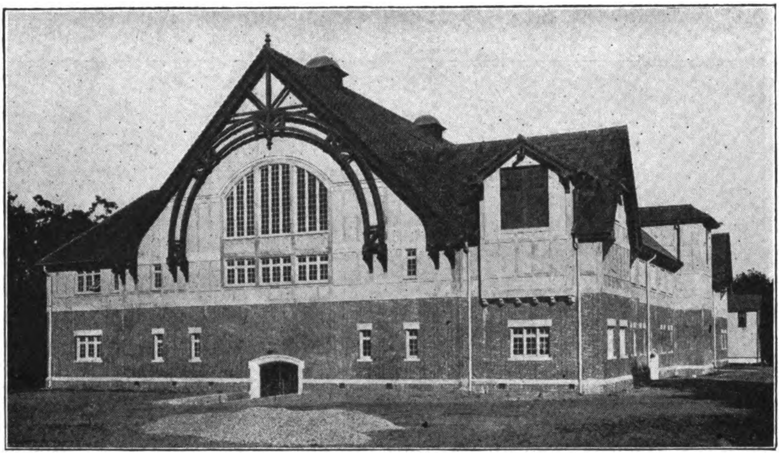


Figure 4. View of the rear and west end of the pavilion, showing entrance to stables and opening to hay loft which provides storage space for 600 tons of roughage.

The large arena gives a favorable opportunity for indoor student work in the winter, and will be used for athletic and gymnastic exercises for agricultural students, ample shower baths and other necessary conveniences being installed for these purposes on the upper floor. The arena will also serve admirably for poultry shows, horse exhibitions, cattle sales, and such agricultural gatherings as occasion may require. The loft has ample storage room for grain, hay and other forage, also considerable space for storage of machinery and other bulky equipment.

From an architectural point of view the building is regarded as one of the most imposing on the grounds, and connected with the central heating station, will cost approximately $80,000. The variety of purposes for which this building will be used makes this new structure one of the most important additions in late years to the resources of the Agricultural College.

STOCK BARN AT HILL FARM.—The condition of the farm buildings at the outlying farm two miles west of the city, known as the

"Hill Farm," has long been a disgrace to a state institution, no repairs having been made on them since they were acquired some twelve years ago. The condition of the stock barn has been such that much loss of forage has occurred annually, while the quarters for live stock have afforded the poorest possible shelter. During this last year a commodious new stock and forage barn, 36x106 feet, has been erected (Figure 5), at an outlay for lumber and materials, as all of the labor of building has been performed

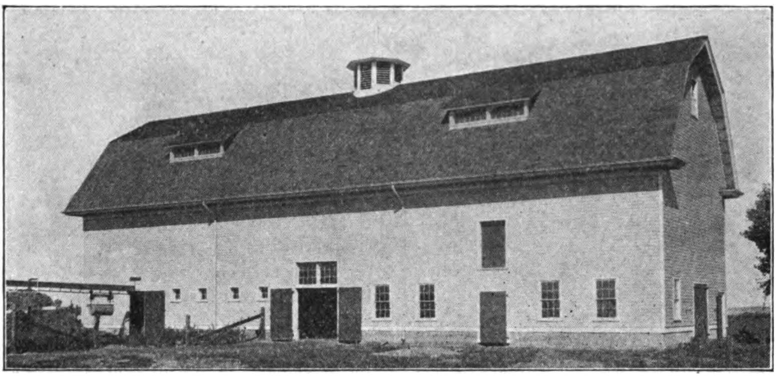


Figure 5. A practical farm barn which might well be adopted as a model for many farms in the state has been erected upon the Hill Farm.

by the regular farm force. This barn accommodates 30 head of horses and cattle, and has provision for 110 tons of forage. This fall for the first time the hay crop and the live stock of the farm are under adequate protection. Blue-print plans of this barn have been prepared for distribution to those farmers who may desire the same. There is a growing interest in the matter of constructing better sanitary buildings on the farm, and those who are intending to build may in this way profit by the suggestions offered.

Plans have been prepared for the rearrangement of all of the outbuildings at the "Hill Farm" so as to have them represent model farm buildings as nearly as possible. A portion of this work has already been accomplished. This equipment will materially improve our experimental resources, as a portion of the live stock and seed supplies are kept on this farm during the summer season.

LAND PURCHASES.—The rapid growth of the University has necessitated the formulation of plans looking forward several de-

cades, and during the past year, plans have been made to cover the location of buildings which will be needed by the University in the future. These contemplate the use of most of the gardens, orchards, and field plots immediately adjacent to the agricultural buildings and now in use by our several departments, as sites for projected buildings for general University uses. To take their place, it is necessary that additions be made to the land holdings of the University. The only available direction for this, contig-

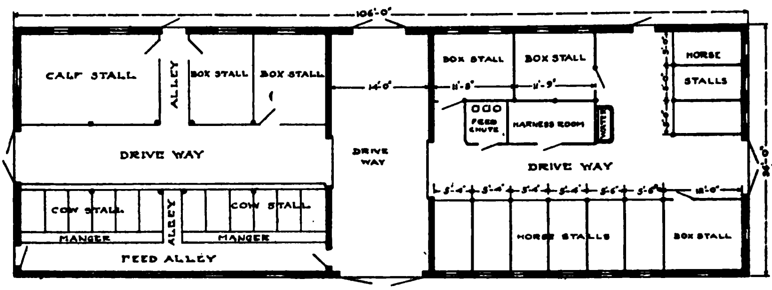


Figure 6. This floor plan shows the convenient arrangement of the Hill Farm barn.

uous to areas now utilized, is to the westward, as the city and the lake effectually check all growth in other directions.

During the past year several purchases have been made in accordance with the plans. Two small tracts, aggregating 8 acres, situated on the crest and sides of a knoll, immediately west of our present holdings, will afford a suitable location for horticultural purposes. Adjacent to this tract on the north, 80 acres have also been purchased, about 25 of which is high land, and the remainder marsh. Subsequently, to control an extensive marsh, most of which is now owned by the University, further purchases of about 58 acres were made. The acquisition of these marsh lands will enable satisfactory drainage improvements to be undertaken, which will result in the reclamation of this area. These lands, when improved, will add greatly to the land resources of the University, and the improvement work will be of the utmost value as a demonstration, for this marsh tract is typical of comparatively large areas in the southeastern and eastern portions of the state.

INCREASE IN FUNDS.—The appropriations derived from the State are not made directly to the College, but are included in the general University appropriations, and are then divided by

the Regents. The rapid increase in our student attendance has necessitated a material increase for teaching needs. The funds derived from the United States government for experiment station work are augmented this year by $2,000, making in the aggregate, on account of the Hatch and Adams funds, $28,000.

AGRICULTURAL EXTENSION WORK.—The most important accession this year has been in the legislative appropriation of $30,000 annually for the next biennium for extension work in agriculture. It has been the endeavor of this College for years to popularize its work by carrying on demonstration work throughout the state. Experience has shown that actual trials and demonstrations of this character are the most effective means of disseminating information, and the recognition of this work by the Legislature in granting the full appropriation asked for indicates the attitude of the state-at-large toward this work.

The agricultural extension work will be organized in two main divisions: (1) Demonstration experiments carried out during the summer months in all parts of the state, and (2) Extension Courses of instruction, consisting of lectures, exercises, and demonstrations by a selected staff, to be given as regular courses of about a week each, during the winter in co-operation with the county schools of agriculture and elsewhere throughout the state.

These courses will be patterned in general after the 10-days Farmers' Course which is held annually in February at the University, and which has grown so rapidly in popularity. By holding similar courses in the different parts of the state a much larger number of people can be reached.

AGRICULTURAL PRESS SERVICE.—A new line of extension work was inaugurated this year in the form of a regular press service for the agricultural journals and newspapers of Wisconsin, prepared by the Station Editor. Recognizing that almost every farmer of the state may be reached through the medium of the agricultural and local press, the preparation and distribution of articles describing the work of this Station, results of experiments and demonstrations, with the advice of the Station staff on special topics, was considered necessary in order to extend the influence of the Station to a greater number of farmers in the state. The publication of suitable matter in such form is often of greater service than the more technical and voluminous Station publication.

Through the medium of the weekly University Press Bulletin,

established in January, 1909, notes on the work of the College and Station were sent regularly to over 100 leading agricultural journals, most of which circulate in Wisconsin to some extent, and to some 350 weekly newspapers in the state. Special articles have also been furnished to newspapers in many localities when any phase of the activities of the Station was of interest to a particular community. Announcements and reports of co-operative experimental work, demonstrations, etc., were furnished to the daily and weekly newspapers.

Photographs and engravings used in Station publications have been loaned to a large number of periodicals to illustrate articles describing the work done at this Station. Special illustrated articles have been prepared by the Editor in many cases. This office has been established with a view of securing the co-operation of the agricultural journals and newspapers in the dissemination of results that should be of value to the farmers of the state. In this way it is possible to reach quickly at least 75 per cent of Wisconsin's farmers.

ORGANIZATION OF NEW DEPARTMENTS AND CHANGES IN STATION STAFF

During the past year two new lines of work have been actively organized—the agricultural Editorial Office and the Department of Home Economics. Mr. J. C. Marquis, formerly associate editor of the Orange Judd publications, was appointed Agricultural Editor July 1, 1908. As editor he has editorial charge of all Station publications, and there will be developed in addition under his direction, work in Agricultural Journalism. There is a rapidly growing demand for men trained in the principles of journalism—indeed this department offers opportunity for experimental work as to elaboration of the best and most effective methods of presenting results. An agricultural press club, known as the Hoard Press Club, named in honor of ex-Governor W. D. Hoard, has been maintained during the past year.

The Department of Home Economics, formerly connected with the College of Letters and Science, was transferred in July, 1908, to the College of Agriculture, and the resignations of the former staff accepted. During this fiscal year the work has been entirely reorganized, Miss Abby L. Marlatt, formerly associated with the Providence (R. I.) Technical High School, having been chosen in April of this year as Professor of Home Economics. The active

work of this department begins with the opening of the fall semester. While primarily the work of this department will be along teaching lines, it is expected that with the unusual facilities in Chemistry, Physics, Physiology, and Bacteriology at the University, that important research on food supplies and cognate problems will be undertaken.

Mr. C. P. Norgord, formerly Professor of Agronomy in the University of Arkansas, was appointed in July, 1908, to the position of Instructor in Agronomy. Mr. Norgord's special duties are largely along extension lines.

Mr. C. S. Hean was appointed Librarian in place of Miss Iva Welsh, resigned October, 1908.

Mr. B. W. Hammer was appointed Assistant in the Bacteriology Department in July, 1908; Mr. Harry Steenbock, Assistant in the Agricultural Chemistry Department, and Mr. H. L. Walster, Assistant in the Soils Department. Mr. Mathias Michels of the Dairy Department, who has been in charge of the extension work in butter and cheese scoring exhibitions, resigned his position in November, 1908, to take up University studies.

The only resignation that has occurred in 1909 has been that of Prof. E. P. Sandsten, in charge of the Horticultural Department, who resigned his chair here at the close of this fiscal year to accept a commercial position with a western fruit raising company.

This fiscal year witnesses the preparation for an unusual increase in the scope of the work of this College, as well as the Station proper. Several new departments have been authorized by the Board of Regents, and will be equipped to undertake research work as rapidly as they can be organized. The following announcements can be made at the present time with reference to departments in which the details of organization have already been perfected.

POULTRY HUSBANDRY.—For many years there has been a considerable demand throughout the state for the organization of a Department of Poultry Husbandry. Few have realized the magnitude and importance of this industry. The aggregate value of poultry and eggs is exceeded in the Union by only three crops—hay, corn, and cotton. Even the beef cattle industry, important as it is, falls much below it. The organization of the work has been placed in the hands of Prof. James G. Halpin of the Michigan Agricultural College, who begins his labors with the opening

of the fiscal year. An entirely new equipment as to buildings and stock will be secured to begin the work at the opening of the fall semester.

AGRICULTURAL ECONOMICS.—A comparatively new but promising line of inquiry that is to be organized for the coming year is the Department of Agricultural Economics. Most experiment stations have concerned themselves mainly with the development of the material side of agriculture, but problems of a social and economic nature are fully as important and worthy of careful scientific endeavor as those concerned with crop or flock production. For several years Prof. H. C. Taylor of the University has been engaged in economic researches along agricultural lines. This year the work has been transferred to the College of Agriculture and the new Department of Agricultural Economics organized, to which is also assigned Prof. D. H. Otis, formerly Associate Professor of Animal Nutrition, who will devote his attention to the subject of farm management.

AGRICULTURAL EDUCATION.—The Department of Agricultural Education is concerned mainly with the problem of introducing agriculture into the secondary schools, and in offering such aid as it is possible for the University to give in the matter of training teachers for this work. State law requires the teaching of elementary agriculture in the graded schools, but as yet the opportunities for the training of teachers are very inadequate. Prof. K. L. Hatch, formerly principal of the Winnebago County Agricultural School, is to have charge of this work, in addition to his work as secretary of the Agricultural Extension Service. This new line of endeavor is largely educational, rather than Station work, but will offer exceptional opportunities for interesting educational experiments.

PLANT PATHOLOGY.—The losses which the agricultural interests suffer through the ravages of plant diseases are an exceedingly heavy tax on this industry, and great advance has been made in the control of these maladies through the discoveries which have been made in the realm of plant pathology. To put this work on the most effective basis, the Regents have authorized the establishment of such a department, and Prof. L. R. Jones, Botanist in the University of Vermont, has been appointed Professor in charge of this new department. Professor Jones will not be able to assume the duties of this office until the middle of the next academic year.

ECONOMIC ENTOMOLOGY.—Heretofore any entomological work carried on by the Station and College has been done by the Horticultural Department. The last Legislature increased materially the scope of the nursery and orchard inspection law, and the time has come for the development of this work on a separate basis. During this year there has been authorized the establishment of a Department of Economic Entomology, and Mr. J. G. Sanders, now associated with the Bureau of Entomology of the United States Department of Agriculture, has been placed in charge of this work. It will not be possible for this department to begin active its work before the middle of the forthcoming year.

CO-OPERATIVE WORK WITH OTHER ORGANIZATIONS.

Our co-operative enterprises with the United States Department of Agriculture have been extended this past year. The work on the investigation of cheese problems with the Dairy Division of the Bureau of Animal Industry has been expanded until there are now detailed at this Station three government experts (a chemist, a bacteriologist, and a cheese maker), who are giving their entire time to this work in conjunction with several members of our own staff.

The investigation of insects affecting the cranberry plant has been made possible by co-operative work with the Bureau of Entomology. This Station has furnished the working plant, superintendence and labor on the practical side, while the government has had one entomological expert in charge and an assistant for a portion of the year. This work will be continued along these lines for another year on the same co-operative basis.

Co-operative arrangements with the Bureau of Plant Industry on the investigation of fiber plants have been continued this year, as last, the work being confined mainly to a study of the adaptability of hemp culture to Wisconsin conditions. Already important practical benefits have been shown to accrue from the conclusions reached.

A line of co-operative investigation has been begun between the Bureau of Plant Industry, the Minnesota Experiment Station and this Station to undertake a study of the question of the best methods of removing stumps from cut-over lands in the northern part of these states. This is a problem of greatest importance to the timber states, and has interfered much with the settlement of

these regions. A careful comparative study of the various methods now in use will doubtless result in reducing expenditures for this purpose.

The Legislature last winter made an appropriation of $10,000 annually for two years to the State Geological and Natural History Survey for the specific purpose of beginning a state soil survey in collaboration with this College. Arrangements have also been perfected whereby co-operation has been undertaken on an equal financial basis with the Bureau of Soils of the United States Department of Agriculture, thus making it possible to cover the work of the survey much more rapidly than was originally expected.

RESEARCH WORK OF THE EXPERIMENT STATION

The last year has witnessed a material improvement in the facilities of the Experiment Station for research work, as it has been possible, in several departments, to secure the additional help necessary to take care of the marked increase in teaching needs.

GENERAL PROGRESS OF STATION WORK

The following brief summary of the more important lines of work under investigation is presented. This summary is merely a statement of the problems with a report on the progress of the work, so as to indicate the nature of the researches under consideration, and does not attempt to present conclusions in final form.

IMPROVEMENT OF NATIVE PLUMS.—Some fifteen years ago, the late E. S. Goff, then horticulturist at this Station, took up the study of our native plums to see if possible improvements could be made. Beginning with the best named varieties, several thousand seedling trees were developed, which were then subjected to a rigid process of selection. Year by year this weeding-out process has gone on, until five years ago this plantation was reduced to about 500 specimens. More and more rigid selection was then exercised to save only specimens that were superior in some special quality. Not only was the size and quality of fruit considered, but special effort was made to develop a type that would be as resistant as possible to the brown rot, and hardy as well as productive. Hopes were entertained that a freestone form might be secured.

The selection process has now been in operation nearly 15 years and of the 25 specimens now in the orchard, about 10 are found to possess superior qualities to most of the named varieties now grown. In the case of one seedling, a type of superlative merit has been obtained. It has a freestone pit that separates quite completely from the pulp, a meaty flesh that is as solid as the European type, and is of excellent quality. For Wisconsin conditions, where the less resistant varieties cannot be successfully grown, this type offers exceptional advantages. This seedling will now be propagated and tested under various climatic conditions to see what influence a different environment may exert on it.

GREENHOUSE INVESTIGATIONS.—Prof. J. G. Moore has continued his studies on the crossing of American and English forcing cucumbers. The English hot-house variety is large in size and has but few seeds, but is often irregular in shape and lacking in prolificacy. Professor Moore has succeeded in crossing this on the more robust and prolific American types, producing a strain that has the good qualities of each. Many of the fruits are wholly seedless, and are of most excellent character. By selection this property has been accentuated until now about two-thirds of the fruits are seedless. The type has not been wholly fixed, but requires further testing before it can be commercially utilized.

CRANBERRY INVESTIGATIONS.—The success of the Station method of handling cranberry bogs was shown most conclusively this year. In fact a more forceful demonstration experiment could not possibly have been arranged. The indications this year were for an unusual crop, but on August 31 and September 1, the temperature on the bogs fell to a point considerably below freezing. On the Station bog where clean culture is followed, the air temperature just over the bogs was 26–27 degrees F, while on neighboring bogs where clean culture is not practiced, the temperature was reduced to 21 degrees F for a considerably longer number of hours. No loss on our clean, sanded bogs was experienced, while from 25 to 75 per cent of the fruit on adjoining areas was destroyed. Wisconsin should have harvested this year not less than 70,000–75,000 barrels, but as a result of this single freeze, the crop returns will be reduced to 30,000–35,000 barrels. This experiment carried out by Nature herself has had more

effect in convincing the growers of the success of the new method introduced by the Station than all of our previous publications.

The work with fertilizers, both phosphate and potash, alone or in combination, showed a marked improvement in vine growth and crop yield. Work on selection of improved strains of wild or cultivated types has been continued. Nearly 200 such strains are now under observation, and data are being collected on prolificacy, keeping-quality of fruit, etc.

The entomological investigations on cranberry insects have been continued this year in cooperation with the Bureau of Entomology of the United States Department of Agriculture, the scientific side being done by Mr. C. B. Hardenberg of the Department, while Mr. O. G. Malde of our Station staff has had charge of the practical culture work on the bog. The work this year has been directed toward a study of certain phases of the life history of the more important insects, especially the vine and fruit worms. Also special studies have been made on the parasites of these insects. It is plainly evident, however, that the growers will not be able to rely upon parasites for the purpose of holding the most undesirable pests in check.

CHEMICALLY BALANCED FEEDING RATIONS MADE FROM SINGLE VS. MIXED PLANT SOURCES.—Reference was made in last year's Report to the inauguration of a cooperative experiment in animal nutrition by the departments of Agricultural Chemistry and Animal Husbandry, in which the attempt was made to determine if a chemically balanced ration compounded from a single plant source was equal to those made from mixed grains. Sixteen young calves in four lots were taken and fed on a ration composed of corn, wheat, and oats, respectively, also a combination of all three nutrients. The animals have now been carried to maturity and undergone the strain of reproduction once, and are being bred again.

Marked differences early manifested themselves. In the early history of the animals, the corn fed lot did much better than any of the other three lots. That difference this year, however, has not been so marked as before. All lots have salt before them when feeding, and it is noteworthy that wide differences exist as to amount consumed, the mixture lot having used nearly six times as much as the oat lot. Striking variations have been observed in the size and vitality of the young produced. The average size of calves from the wheat-fed lot when dropped was 46 pounds,

while those from the corn lot was 73 pounds. The milk production of the wheat lot has been abnormally low, while the physical characteristics of the milk from different lots show material variation in the nature of the butter fats produced.

The experiment has opened a wide field of inquiry that is sure to lead to most important results in the matter of animal nutrition. It is apparent that the usually accepted dictum that a chemical analysis is all that is necessary to balance properly a suitable ration, is far from correct.

RÔLE OF THE INORGANIC ASH ELEMENTS IN ANIMAL NUTRITION.—In the cooperative work last year between the Animal Husbandry and Chemical departments, on the question as to the possibility of replacing in a nutritive ration, organic phosphates with inorganic phosphorus compounds, it appeared that the calcium salts also played an important rôle. Experiments have been conducted with growing swine, in which a corn ration has been fortified with different lime salts. While a well developed skeleton could be produced in this way, the soft tissues were not normal. Where lime salts have been used with mixed grain rations, not much difference was noted as to rate of growth, but again, the skeletal development with those receiving phosphates of lime was much more pronounced, and stronger bones were produced. It would seem that all grain rations usually fed swine are too low in lime for best development, and that either added calcium salts, such as phosphates, or plants like clover or alfalfa, which are very rich in lime should be added. The growing animal and the brood sow during the development of her young require an increased supply of this element.

In these studies the question has arisen as to whether the animan can actually utilize phosphorus wholly in inorganic form. Professor McCollum's experiments on rats have shown that such a supply can be used if great care is taken to make the food taste different from day to day. This demonstration that animal life can utilize purely inorganic salts for the manufacture of the organic body compounds brings the subject of animal nutrition into closer relation than ever with plant processes.

NUTRITION STUDIES ON DAIRY HERD.—This year completes the 3-year period in which Professors Humphrey and Woll have continued their studies on the influence of a medium protein ration for the economic production of butter-fat in the University herd. Nine years' observations have now been completed in which the

herd has been fed for periods of three years each on medium, then a high, and for the third period, again a medium, protein ration. Comparative studies of the influence of these rations for this long feeding period are now in progress.

RECORD OF THE DAIRY HERD.—The general improvement of the University dairy herd still continues to be maintained. During the year 25 cows in the herd gave an average of over 8,400 pounds of milk producing 363.6 pounds of butter fat, or 31.3 pounds of fat more than any other year's record of the herd. The value of products produced averaged $111.76 per animal, while the feed consumed was worth $50.34.

The phenomenal record of the Jersey cow Double Time, the 7-day official test of which was reported last year, has been maintained this year, as her yearly test, ending May 12, 1909, showed a production of 14,521 pounds of milk, having 691.3 pounds of butter fat, or equivalent to 806.5 pounds of butter.

SOIL STUDIES.—Professor Stoddart has continued the work on soil phosphates this year. His previous work had shown the deficiency of acid soils in available phosphates. The explanation now offered for this condition is that the ratio of iron and aluminum phosphates to phosphate of lime is greater in acid than in non-acid soils. He finds that a determination of the calcium phosphate as distinguished from the iron and aluminum salts of this element is a satisfactory means of measuring the phosphorous which may become available to crops.

Professor Whitson's studies on humus accumulation in the soil have shown that the heavy annual manuring of such lands as tobacco soils does not increase the total organic matter nor the nitrogen present in the same. The surprising condition is determined that in a large number of such cases continuous tobacco culture even with heavy manuring has resulted in a loss of a third of total organic matter and nearly as much nitrogen.

TREATMENT OF DIFFERENT SOIL TYPES.—The work on the improvement of sandy soils has been continued, the results this year being better with soy beans than with the lupines. The use of peat as a source of nitrogen has proven profitable for this type of soil, where it was readily available. Most of the sandy soils are found to be acid, and the addition of ground limestone has proven to be highly beneficial in aiding in the development of clover.

The marsh soil work this year has been a continuation of previous experiments, the results of which verify the conclusions

formerly deduced that phosphate and potash are frequently required on the virgin peat soils. At the Soils Station at Phillips, good crops of barley and potatoes were secured under this treatment.

CHEDDAR CHEESE INVESTIGATIONS.—The cooperative experimental work with the Dairy Division of the United States Department of Agriculture has been continued this past year. The experimental work on making cheddar cheese from pasteurized milk has been continued, and some very encouraging results have been obtained. The studies are yielding results on the complex nature of the changes involved. An analytical study of some of the factors which aid in the separation of whey from the curd in the vat has been made, the results of which will be published this fall.

Interesting data have been secured on the effect which different sizes of curd knives exert on the changes in curd masses of varying size. It has been shown that the separation of moisture progresses more rapidly at a moderate degree of acidity than when the acidity is extremely low or high. The use of high temperatures and rapid heating with over-ripe milk showed no more complete moisture separation than by more moderate treatment, while the loss of cheese solids was greater.

STUDIES ON RIPENING CHEESE.—A portion of the co-operative work with the Dairy Division of the United States Department of Agriculture has been directed this past year to the problem of separating and tracing the origin of the volatile compounds in ripening cheddar cheese to see if it was possible to throw any light on the complex problems of the development of cheese flavor. This exceedingly complicated organic study has been carried out by Mr. S. Y. Suzuki, the federal expert, in cooperation with Professor Hart. Much progress has been made in this study, but the results so far are of such a character as to make their announcement preferable in bulletins of the technical series.

PURIFICATION OF CREAMERY SEWAGE.—Investigations have been made by the department of Dairy Husbandry to apply the septic tank method of sewage disposal to creamery sewage. A small experimental plant, designed by Dean Turneaure of the College of Engineering, was constructed three years ago to serve as a basis for this experimental work. It has been shown that creamery wastes are, however, much more resistant than domestic sewage, and that retention for ordinary periods of time will not produce a non-putrescible effluent. Chemical analyses on several plants

throughout the state have also been made. If the reduction tanks are made large enough to hold the sewage for five or six days, a reasonably satisfactory effluent may be produced. The use of sand or cinder filters to purify further the septic tank effluent has been studied to some extent, but no conclusive data as yet determined.

PEDIGREED BARLEYS.—This year witnesses the completion of eleven years of work on the part of Prof. R. A. Moore to improve the strains of barley best adapted to Wisconsin conditions. Thirteen pedigreed varieties have been developed in this time from which four or five will be chosen to be pushed. While the yield of these strains has been somewhat higher than that of the select Oderbrucker or Manshury types, their superior malting properties and absolute uniformity makes them especially valuable.[1] The Station has now accumulated about 1,500 bushels of these pedigreed strains which will be distributed mainly through the medium of the Experiment Association.

IMPROVED TYPES OF TOBACCO.—Work on improvement of tobacco by hybridization and selection has been continued this year by the Horticultural department. Crosses were secured in numerous cases and several strains of promise have been developed. These must, however, be tried out for several years before their real value can be determined.

NEW AND VALUABLE CROPS.—Experiments have been conducted by the Agronomy department on the growth of hemp this past year at Waupun and Mendota, the yields ranging from 1,400 to 1,550 pounds of straight fiber and tow per acre. At current prices this made the crop yield about $75 to $90 per ton. On good clay or muck soils this crop seems to do well. While hemp is probably too expensive for binder twine, it is extensively used in manufacture of fine twine and cordage.

PUBLICATIONS

CHANGES IN STATION PUBLICATIONS

The plan proposed last year of changing the manner of publishing the results of Station effort has been put into effect this year. As then outlined, the following plan is now pursued:

[1] At the National Corn Exposition at Omaha this fall these pedigreed strains took the highest prizes offered in the world's classes.

1. The results of experimental work that are directly available for the use of farmers will be presented in the regular bulletin series of the Station. It is designed to make these bulletins brief, covering a single definite problem, and where possible, well illustrated, so that they may be easily understood by all classes.

2. The more strictly scientific and technical results will be presented in a new series of bulletins entitled "Research Bulletins," which will be published in small editions and not given general distribution. These are distributed upon issuance to scientific workers and the agricultural press. During the last fiscal year six such bulletins have been issued. These Research Bulletins together with the Annual Report of the Director, which is also distributed as a bulletin of the regular series, will be bound together at the close of each fiscal year and will constitute the Annual Report of the Station, which will be sent to libraries, public institutions, and to such persons as may be especially desirous of maintaining a file of the scientific results of the Station. Such a plan as this is designed to economize in the matter of public printing, as separate mailing lists will be maintained for scientific workers and the general public.

To put this plan into operation this year, it has been necessary to revise our general mailing list. Heretofore our general state list, to which has been sent practically all publications of the Station, has aggregated about 15,000. This has been supplemented by special lists, such as operators of creameries and cheese factories, tobacco growers, cranberry growers, feed dealers, stallion owners, and the like, making the maximum distribution of our larger editions about 29,000. During the past year this general list has been revised so as to eliminate all "dead timber," such as changes of address, deaths, and those who might not care for these publications. It is gratifying to note that the reduction in the general mailing list has been only a few thousand, with return cards for continuance still being received daily.

Special attention is here called to the fact that the publications of the Station are free to all residents of the state and it is the privilege of any individual to ask that the same be mailed to him. On the other hand, in order that they may reach those who are interested in this work, the Station asks that application be made, if the same is desired. A postal card stating this fact, addressed to the Experiment Station, Madison, is all that is needed to have a name placed on the list.

PUBLICATIONS IN SCIENTIFIC JOURNALS.—The inauguration of the Research series of Bulletins of the Experiment Station is especially designed to present the results of the more technical work accomplished. This type of work of the American experiment stations has suffered neglect to a considerable extent at the hands of the scientific man engaged entirely in University work, because the Station reports and bulletins were not always directly available. It has therefore been deemed advisable to encourage members of the Station staff in the presentation of experimental results, under certain conditions, in the regular scientific journals, so that results would be made immediately available to all scientific students.

The following list presents such publications as have appeared during this fiscal year.

TECHNICAL PUBLICATIONS, 1908–1909

The Rôle of Inorganic Phosphorus in the Nutrition of Animals.—E. B. Hart, E. V. McCollum, and J. G. Fuller, Amer. Journ. Physiol., Vol. 23, p. 246.

The Rôle of the Ash Constituents of Wheat Bran in the Metabolism of Herbivora.—E. B. Hart, E. V. McCollum, and G. C. Humphrey, Amer. Journ. Physiol., Vol. 24, p. 86.

The Relation of Different Acids to the Precipitation of Casein and to the Solubility of Cheese Curds in Salt Solution.—J. L. Sammis and E. B. Hart, Journ. Biol. Chem., Vol. 6, p. 181.

Volumetric Method for the Estimation of Casein in Cows' Milk.—E. B. Hart, Journ. Biol. Chem., Vol. 6, p. 445.

Nature of the Acid Soluble Phosphorus Compounds of some Important Feeding Materials.—E. B. Hart and W. H. Tottingham, Journ. Biol. Chem., Vol. 6, p. 431.

Quantitative Estimation of Lactic Acid in Cheddar Cheese.—S. Y. Suzuki and E. B. Hart. (Waiting for the approval of the Secretary of Agriculture. Journal not yet selected.)

Soil Acidity in its Relation to Lack of Available Phosphates.—C. W. Stoddart, Journ. Indust. Eng. Chem., Vol. I, No. 2, p. 69.

New Separations in the Yttrium Group by Means of Stearates and Selenates.—C. W. Stoddart, published by the author in Madison.

The Milking Machine as a Factor in Milk Hygiene.—E. G. Hastings and C. Hoffmann, Centb. für Bakt., etc., II, Abt., Vol. 22, p. 222.

Note on a Group of Lactic Acid Bacteria not previously described in America.—E. G. Hastings, Science N. S., Vol. 28, p. 656.

A number of texts on various phases of agricultural work have also been published by different members of the staff during the past year.

PUBLICATIONS ISSUED.

In this fiscal year, thirteen bulletins of the regular series, aggregating 415 pages, and 6 technical bulletins of the Research series, embracing 200 pages, have been issued, and distributed. In addition to these, two special bulletins, giving lists of feeding stuffs and fertilizers have also been prepared for the special use of the trade concerned.

The following list and brief synopsis of these publications is herewith presented.

No.	Title.	Author.	Size of edition.	Number of pages.
	REGULAR BULLETINS			
164	The King System of Ventilation......	Ocock...............	50,000	24
165	Vaccination Against Tuberculosis in Cattle with Bovo-vaccine (Von Behring).........................	Russell and Hoffman	27,000	13
166	Disinfection and Commercial Disinfectants............................	Ravenel and Smith..	35,000	19
167	The University Dairy Herd: Management and Records 1907-1908..........	Humphrey and Woll	25,000	27
168	Spraying Potatoes Against Blight and the Potato Beetle................	Sandsten & Milward	30,000	27
169	Progress in Wisconsin Horse Breeding	Alexander..........	7,000	56
170	Licensed Commercial Feeding Stuffs, 1908................................	Woll.................	20,000	96
171	Report of the Director, 1908...........	Russell..............	27,500	35
172	Tests of Dairy Cows, 1907-1908.........	Woll and Harris.....	15,000	33
173	Milking Machine Experiments........	Woll and Humphrey	25,000	30
174	The Conservation of Phosphates on Wisconsin Farms....................	Whitson & Stoddart	40,000	20
175	A Three Year Campaign Against Bovine Tuberculosis in Wisconsin..	Russell and Hoffman	27,000	18
176	The Improvement of Wisconsin Tobacco Through Seed Selection.......	Sandsten............	6,000	17

No.	Title.	Author.	Size of edition.	Number of pages.
	RESEARCH BULLETINS			
1	The Rôle of Inorganic Phosphorus in the Nutrition of Animals............	Hart, McCollum and Fuller..............	3,000	38
2	Factors Influencing the Phosphate Content of Soils........................	Whitson & Stoddart	3,000	20
3	The Efficiency, Economy and Physiological Effect of Machine Milking...	Woll and Humphrey	4,500	75
4	The Germination of Pollen............	Sandsten.............	4,500	20
5	The Rôle of the Mineral Elements in the Metabolism of Herbivora.	Hart, McCollum and Humphrey.	4,500	16
6	Studies on the Bacterial and Leucocyte Content of Milk.	Hastings, Hoffman and Hammer......	4,500	30
	SPECIAL BULLETINS			
	Mch. 1909. List of Feeding Stuffs and Fertilizers Licensed for Sale in Wisconsin, 1909........................	Woll..................	2,500	12
	Apr. 1909. List of Feeding Stuffs and Fertilizers Licensed in Wisconsin, 1909 (Revised)	Woll..	1,500	12

REGULAR BULLETINS

BULLETIN 164. THE KING SYSTEM OF VENTILATION. This bulletin presents a brief illustrated description of the essentials of the King system of stable and barn ventilation, which was devised at this station some years ago by Prof F. H. King, showing proper methods of installation in barns constructed of various materials. The drawings are devised to give the farmer and builder sufficient knowledge of the system to enable him to construct effective ventilators at moderate cost. Estimates of cost of construction are also presented.

BULLETIN 165. VACCINATION AGAINST TUBERCULOSIS IN CATTLE WITH BOVOVACCINE (VON BEHRING). Experiments to determine the value of bovovaccine as an aid in eradicating bovine tuberculosis from a herd are described in this bulletin. The significance of the results is discussed with relation to the practical value of the method. The method is considered of doubtful value for use by Wisconsin farmers in view of the expense of the process, time involved in immunizing the animals and the fact that only young stock can be treated and must be kept separate from sources of infection during the immunizing process.

BULLETIN 166. DISINFECTION AND COMMERCIAL DISINFECTANTS. This bulletin presents a popular discussion of disinfection, the essential constituents of the principal disinfectants, methods of applying same in various places, such as stables, barns, etc. The results of tests of nine well known commercial disinfectants are presented.

BULLETIN 167. THE UNIVERSITY DAIRY HERD; MANAGEMENT AND RECORDS, 1907–1908. The management and performance of the University dairy herd for the year is described briefly in this bulletin,

which contains illustrations of the best animals of the herd. The description of the methods followed in keeping these animals during both summer and winter periods is presented for its practical value to stockmen in general.

BULLETIN 168. SPRAYING POTATOES AGAINST BLIGHT AND THE POTATO BEETLE. This bulletin reviews the experimental work in potato spraying done by the Station in eight counties of the state. The beneficial results of such spraying for blight are emphasized. A popular discussion of the nature of potato blight and the best methods of spraying to hold this trouble in check are outlined and suggestions in the selection of spraying machinery are given. Methods to be followed for the control of the potato beetle are also described.

BULLETIN 169. PROGRESS IN WISCONSIN HORSE BREEDING, with lists of stallion licenses and transfers for 1908. This bulletin reviews the improvement of the horse breeding industry of the state as a result of the operation of the Wisconsin stallion law which went into effect January 1, 1906. The elimination of unsound stallions with the introduction of pure-breds in their places is shown by the statistics. A review of the progress in the enactment of stallion legislation in other states is also presented. List of stallions and jacks licensed in 1908, as well as transfers of licensed animals made during the year are included in this bulletin.

BULLETIN 170. LICENSED COMMERCIAL FEEDING STUFFS, 1908. In accordance with the provision of the Wisconsin feeding stuffs law, a list of licensed manufacturers and dealers, together with analyses of feeding stuffs collected during 1908, are presented in this bulletin. The beneficial effects of feed inspection are shown by the absence of adulterated samples among those analyzed during the last three years and the marked reduction in samples pronounced suspicious. A discussion of the character of the licensed feed as related to the analyses is also included. The text of the feeding stuffs law appears in the bulletin.

BULLETIN 171. REPORT OF THE DIRECTOR, 1908. This bulletin presents a summary of the work of the Station for the fiscal year ending June 30, 1908. The activities of the Station along the lines of administration, research work, publication and extension service are briefly described to show the progress made during the year. The rapid development and importance of the extension service is emphasized in the descriptions of the many lines of demonstration, general extension and inspection work.

BULLETIN 172. TESTS OF DAIRY COWS, 1907–1908. This bulletin presents a summary of official tests of dairy cows conducted by the Station during the year ending October 1, 1908. A review of the tests made by the Station since 1893 is included. The bulletin includes illustrations of some of the best animals tested during the year representing the three principal breeds tested.

BULLETIN 173. MILKING MACHINE EXPERIMENTS. A popular discussion of trials made with a milking machine on the Station herd with a discussion of the efficiency, economy and bacteriological effects of the machine are presented in this bulletin. Opinions obtained from a large number of dairy farmers who have used this machine under practical conditions are also summarized.

BULLETIN 174. THE CONSERVATION OF PHOSPHATES ON WISCONSIN FARMS. The importance of phosphates to the agriculture of the state, description of how phosphates are removed from farms, together with an outline of the best methods of maintaining soil phosphates, as shown by experiments conducted by this Station, are presented in this

bulletin in popular terms. The beneficial effect of phosphate fertilizers when applied to lands in several parts of the state are duly emphasized in the discussion of experiments made with phosphate fertilizers.

BULLETIN 175. A THREE YEAR CAMPAIGN AGAINST BOVINE TUBERCULOSIS IN WISCONSIN. This summary of the educational campaign, which has been conducted in Wisconsin for three years, includes a discussion of the tuberculin tests together with data on the distribution of the disease throughout the state. The need for immediate action to hold the disease in check in the northern part of the state where it is just getting a foothold, as well as the great importance of dairymen exercising continual vigilance in their herds, is duly emphasized.

BULLETIN 176. THE IMPROVEMENT OF WISCONSIN TOBACCO THROUGH SEED SELECTION. This bulletin presents a review of methods followed by the Station in its tobacco improvement experiments during the past five years. Suggestions to growers as to how they may select seed plants, harvest, and test the seed in order to secure best results are also outlined. Suggestions to be followed by practical growers in their efforts to improve their own seed are presented.

RESEARCH BULLETINS

RESEARCH BULLETIN NO. 1. THE RÔLE OF INORGANIC PHOSPHORUS IN THE NUTRITION OF ANIMALS. This bulletin presents the results of two sets of experiments to secure new data on the comparative value of certain forms of phosphorus-bearing materials for the young, growing animal; the nutritive value of inorganic phosphates when added to rations low in phosphate; the fundamental processes of organic phosphorus building in the body; the influence of the efficiency of phosphorus in the food on the body of the animal; and the minimum phosphorus requirements of young, growing pigs. The results present valuable information on a comparatively new phase of animal nutrition problems.

RESEARCH BULLETIN NO. 2. FACTORS INFLUENCING THE PHOSPHATE CONTENT OF SOILS. This bulletin presents two discussions on soil phosphates. The phosphate content of soils as affected by methods of farming shown by comparative analyses of virgin and tilled soils is presented and the phosphate availability in its relation to soil acidity as shown by the history and analyses of soils from many fields is also discussed.

RESEARCH BULLETIN NO. 3. THE EFFICIENCY, ECONOMY AND PHYSIOLOGICAL EFFECT OF MACHINE MILKING. This bulletin includes the details of an extensive investigation with a milking machine, which has been popularly described in Bulletin 173 of the regular series. Available and extensive data representing the results of investigation at the Station and experience of practical farmers are included. The effect of machine milking upon the udders of the cows is given by the Station Veterinarian. The bacterial content of machine-drawn and hand-drawn milk is also shown by the investigations made by the Bacteriological Department.

RESEARCH BULLETIN NO. 4. THE GERMINATION OF POLLEN. This bulletin describes an investigation of some conditions which influence the germination and fertility of pollen. Laboratory and field experiments were conducted with pollen from different varieties of fruit trees, and the results of various conditions and temperatures of the atmosphere and their relation to the formation of pollen and the subsequent yield of fruit are shown.

RESEARCH BULLETIN No. 5. THE RÔLE OF THE MINERAL ELEMENTS IN THE METABOLISM OF HERBIVORA. This investigation presents new data on the effect of phytin in various forms upon the digestive processes of a cow in order to show the effect which this material and these constituents have upon the product and body of the animal.

RESEARCH BULLETIN No. 6. STUDIES ON THE BACTERIAL AND LEUCOCYTE CONTENT OF MILK. This bulletin includes three papers on the following subjects: The bacterial content of milk of individual animals; Experimental leucocytosis in the cow's udder, and The occurrence and distribution of organisms similar to the Bacillus bulgaricus of Yogurt. These articles present the results of investigations conducted by the Bacteriological department on various phases of dairy bacteriology.

AGRICULTURAL EXTENSION SERVICE

Important as is the work of teaching in the betterment of agricultural conditions, the work of extension is of more immediate value. The best results of teaching here at the College will only directly influence the coming generation; the results of extension effort are, however, immediate in their application, for they reach the man who is tilling the soil today.

For the purpose of organizing this new line of effort more effectively, the last legislature made a specific appropriation of $30,000, but this did not become available until the close of the present fiscal year; yet the importance of this extension work, as indicated by the demand for the same, has been such that the College has pushed it as vigorously as possible. The result has been that much more has been accomplished along these lines than in previous years. In organizing this work on the basis of the new appropriation it is highly important that the same be planned in a most careful manner, so as to secure the greatest returns with the funds available for this purpose.

The plan of organization which has been adopted is to develop this extension service as far as possible in connection with each department of the College, realizing the necessity of having each line of College work, if possible, brought directly in contact with the people of the state. It is to be hoped that such a plan will keep the work on a practical basis and at the same time render the activities of the department more homogeneous than would be the case if the extension service was segregated in a special department, under a separate staff.

ORGANIZATION OF THE EXTENSION WORK

This extension work naturally divides itself into two main groups of effort:

(1) The extension by demonstration of the results of experimental or research work,

(2) The extension by teaching courses and otherwise, of general agricultural information, to persons unable to attend the University.

The two lines inevitably overlap. Therefore, the distinction sometimes made that extension work should be placed under the two heads, Station and College extension, is one which is too refined to be of much practical service. It seems preferable to combine this work for the state-at-large under the general head of extension. The rapidity with which this extension idea has developed within the last few years is indicative of the great interest now being attached to the education of the masses by new educational methods.

The plan of organization that is being developed at Wisconsin is as follows:

1. Field Demonstration Work.
2. General Extension Activities.
3. Control or Inspection Work.
4. General Information Work.
5. Extension Courses of Instruction held in conjunction with the County Agricultural Schools and elsewhere.

In organizing this work for the coming year, it is essential to state explicitly just what lines of effort will be put into operation and how the benefits of such service may be obtained. For this purpose a special publication has been issued (Circular of Information No. 7) giving in detail the various lines of work. This may be secured by anyone upon application.

In order that the agricultural public may have proper information as to this Service and how it can be obtained, a summary statement is here presented, giving the respective lines of work that have already been organized. Correspondence can be addressed to the individual department interested or to Agricultural Extension Service, College of Agriculture, Madison, Wis.

OUTLINE OF AGRICULTURAL EXTENSION SERVICE

AGRONOMY

PURE-BRED SEED DISSEMINATION. Improved grains and forage plants are disseminated, principally, through members of the Wisconsin Experiment Association, an organization of graduates and former students of this College. Centers are established for propagation purposes from which such grains are distributed. This Station does not undertake to sell these seeds commercially, but will place inquirers in touch with parties known to have select stock.

CROP DEMONSTRATION FARMS.—Demonstration centers have been established on a number of the county and state farms connected with asylums and other state institutions, so that the propagating work in pure-bred seeds may be more readily brought before farmers of the various vicinities. A few new farms will be added to the number yearly.

YOUNG PEOPLE'S SEED CONTESTS.—In cooperation with county fair organizations and the county superintendents of schools pure-bred seed is furnished for distribution to boys and girls to be planted, under directions furnished, and the crop exhibited at the respective county fairs. These contests are designed to awaken the interest of the young people in agriculture and to further disseminate pure-bred seeds.

WEED IDENTIFICATION.—Specimens of noxious weeds and other plants will be identified where satisfactory specimens are sent for examination. Information relative to the use of chemical solutions for weed control and eradication is supplied upon application.

SEED INSPECTION.—All seeds of grains and grasses, according to the State Seed Inspection law, must be examined for purity and germination, and be properly branded before being sold. The execution of this law is under the control of the Station and necessary details will be furnished upon application. Samples shipped in accordance with directions to the State Seed Inspector, will be examined free of charge to farmers who have purchased the seed. Samples sent by dealers, seedsmen or growers to comply with the law, should be accompanied by the authorized fee of 25 cents per sample.

ANIMAL HUSBANDRY

COMMUNITY BREEDING ASSOCIATIONS.—This department will assist in the organization of breeding associations, furnishing outlines of constitution and bylaws, and, to a limited extent, speakers will also be sent to address already existing associations.

LIVE STOCK JUDGING.—Lists of persons available for judging live stock at county fairs and other exhibitions, will be furnished upon application.

BACTERIOLOGY

TUBERCULOSIS POST-MORTEM DEMONSTRATIONS.—In cooperation with the State Live Stock Sanitary Board, a limited number of tuberculosis post-mortem demonstrations will be given at agricultural fairs and assemblies during the fall and winter seasons, when previously arranged for.

CONTROL OF ANIMAL DISEASES.—In cooperation with the State Live Stock Sanitary Board, aid will be given in the investigation of animal disease outbreaks. Samples of tissues to be examined should be sent

in accordance with proper directions, which will be furnished upon application. Examination of animal tissues suspected of containing poison, or samples of suspected water cannot be made by the Station. Analysis of waters should be referred to the State Hygienic Laboratory, Madison, Wisconsin. No attention will be paid to samples for analysis unless all charges are prepaid.

CHEMISTRY

MANURE PRESERVATION TESTS.—Cooperative experiments will be arranged with farmers to test the value of different methods of manure preservation.

CASEIN TEST DEMONSTRATIONS.—Upon request, arrangements will be made to demonstrate the applicability of the Hart Casein Test to factory use.

DAIRY COW TESTS.—Certification of the production of pure-bred dairy cattle is made by an authorized representative of the Station. Such official tests are continued as desired from one to 30 days, or more, the actual cost of the same being borne by the breeder.

WISCONSIN DAIRY COW COMPETITION.—This competition is designed to stimulate testing of dairy cattle as to performance, and encourage business methods in management. A prize fund, amounting to $2,600, has been raised, and awards will be made for maximum records of butter fat produced by individual animals and herds. Entries in this competition will close Nov. 1, 1910, and awards made on basis of records completed prior to Nov. 1, 1911.

FEED INSPECTION.—Concentrated feeds, (except whole seeds and unmixed meals made from the same) must be licensed for sale in this state, and should be labeled as to minimum fat and protein, and maximum fiber content. Samples of commercial feeding stuffs (taken in accordance with prescribed directions) will be analyzed for farmers free of charge.

FERTILIZER INSPECTION.—The sale of all commercial fertilizers in the state is under Station control, the law requiring the analysis of all such fertilizers and their license, each sack to show manufacturer's guarantee for minimum nitrogen, total and available phosphoric acid, and soluble potash.

DAIRYING

BUTTER AND CHEESE SCORING EXHIBITIONS.—Factory operators in cheese factories and creameries may join these monthly scoring exhibitions upon application, and have their factory product scored and criticised, in order to secure assistance in maintaining a uniformly high quality of product. Entry blanks for such exhibitions will be furnished upon application.

STARTER DISTRIBUTION.—To aid factory operators in the control of cream ripening, pure culture starters, prepared in the Bacteriological department, will be furnished, upon application to those who participate in the butter and cheese scoring exhibitions.

MILK AND CREAM TESTING.—Samples of milk and cream will be tested free for farmers and factory owners under prescribed conditions. Samples must be prepaid and sent in accordance with regulations.

ECONOMIC ENTOMOLOGY

NURSERY INSPECTION.—All nursery stock grown and offered for sale in the state must first be examined by the state nursery and orchard inspector, the legal fee for which is $10 per nursery, and $1 for each agent.

EDUCATION

RURAL AND HIGH SCHOOL AGRICULTURE.—The compulsory teaching of agriculture in the rural schools, and the increasing interest in this work in the other public schools of the state have led to a rapidly increasing demand for definite information relative to the best methods of instruction. A special series of circulars to cover needs of teachers is now in process of preparation, and all bulletins and such circulars as are adapted to this demand will be mailed free to all the rural school teachers applying directly, or upon application to the county superintendents. Lantern slides for lecture purposes will be loaned to schools upon application. The department can furnish a limited number of lecturers on this line of educational work.

ENGINEERING

BUILDING PLANS.—Blue prints of farm buildings (barns, hog houses, cow stalls, silos, cement work), ventilation plans of school houses, stables, etc., diagrams showing methods of belt lacing, rope splicing, knot tying, and rope halters, will be furnished upon application.

HORSE BREEDING

STALLION LICENSING.—All sires used for public service in the state must first be licensed by this department, and the certificate recorded with the county register of deeds. License certificate must be printed and posted wherever an animal is used for service. Unsound horses cannot be licensed. Speakers for meetings designed to aid in horse improvement work may be arranged for upon application.

HORTICULTURE

POTATO SPRAYING DEMONSTRATIONS.—Field demonstrations, to illustrate methods of controlling potato blight and other fungus diseases, will be made in a number of the counties particularly interested in potato culture. The Station furnishes, free of charge, machinery, chemicals, and a representative to supervise the work, the farmer doing all the necessary work connected with the demonstration. Field meetings for instruction to a community will be held when the spraying work is in progress and at harvest.

ORCHARD SPRAYING DEMONSTRATIONS.—Field demonstrations to illustrate methods of control of fungus and insect diseases infesting orchards, will be held under the same conditions as in potato work.

TOBACCO SEED DISTRIBUTION.—The distribution of select tobacco seed that has been developed at the Station will be made again this coming spring. After this season, general distribution will be discontinued, as now a large part of the tobacco grown in the state is of this variety.

DECORATION OF SCHOOL GROUNDS.—Plans for decoration of school grounds will be furnished free of cost to two schools in each county upon application. Where a special visit is required to perfect plans, traveling expenses must be borne by the school. The Station cannot furnish nursery stock, but will aid individuals in selecting plants, trees, and shrubs for ornamental or useful purposes.

SOILS

COOPERATIVE FERTILIZER TESTS.—Arrangements may be made for cooperative fertilizer tests to demonstrate the effect of phosphates on clay soils, the effect of special fertilizers, drainage, and crop adapta-

tion, to marsh soils and the treatment of sandy soils. The Station furnishes the necessary fertilizers and other material for the experiment, while the owner cares for, and keeps a record of the crop.

This Station does not analyze miscellaneous samples of soil, except where examination is made of the immediate condition.

SOIL DEMONSTRATION PLOTS.—Demonstration plots on typical soils have been established in various portions of the state to study and show methods of treatment applicable to special soil conditions. Such soil plots have already been located on the red clays at Superior and Ashland, on sand at Sparta, Iron River and Spooner, and on marsh soils at Marinette, Mather, and Phillips.

DRAINAGE SERVICE.—Plans are made for drainage systems and, when required, aid is given in the organization of drainage districts with plans and specifications for either tile or open ditch drainage.

SUB-STATIONS

NORTHERN SUB-STATIONS.—In order to study the best methods of treatment on other soil types than those which occur at the central Station at Madison, three branch or sub-stations have been located in the northern part of the state,—two on the Lake Superior red clays, at Superior, and Ashland, and one on light sandy soil at Iron River. In addition to these stations, which have been in operation for several years past, a new sub-station is now being located at Spooner on the jack-pine sandy soils.

CRANBERRY SUB-STATION.—Investigations of cranberry culture and methods of control of insect and fungus diseases are carried on at the Cranberry Sub-Station, located at Cranmoor (postoffice Grand Rapids, Wis.). Persons interested in cranberry culture may obtain the services of the Sub-Station Superintendent in making preliminary surveys of marsh areas, also advice, and assistance in laying out and managing cranberry bogs at the cost of his expenses for travel.

MISCELLANEOUS

STUMP REMOVAL INVESTIGATIONS.—In cooperation with the United States Department of Agriculture, and the Minnesota Experiment Station, this Station has the investigation of the most efficient and economical methods of removal of stumps from cut-over lands under way. Such aid as it is possible for the expert in charge to render will be furnished free of cost.

DEMONSTRATION WORK

As our experience with the demonstrative lines of extension work increases, it becomes more and more apparent that better results are obtained where the instruction is given by demonstration so far as the nature of the work will permit. Habits of thought have a strong tendency to become fixed. We are apt to do the things we need to do in the same old way, and it is difficult to change methods that have long been in vogue. An actual demonstration, however, affords the most convincing proof and will carry conviction where frequently all other methods fail. During the past year these demonstration lines of work have been materially increased over those of the preceding year.

COOPERATIVE FERTILIZER TESTS.—Although the soil fertility of this state has not been impaired, on the average, to the extent that it has in many other regions, by reason of the development of animal husbandry, yet, the examination of soils by the Soils department in different regions of the state indicates the necessity of attention being directed to this matter before further exhaustion follows. Cooperative tests have been undertaken in a number of cases with farmers where rock phosphate has been used to supplement barnyard manure. Even on dairy farms where supposedly the fertility was being maintained, the addition of phosphate has been found to be highly advantageous.

In tests made in Richland county the hay crop was increased over a ton per acre by adding raw phosphate rock to the manure over the yield obtained by the use of manure alone. In Door county, a barley crop was increased one-third or 15 bushels per acre. An application of phosphate fertilizer, costing $2.50, increased the crop yield from $9 to $12 per acre.

Arrangements are being made to extend these tests materially the next season. The importance of this work is being readily recognized, and although phosphate has only been used in the state for a few years, interest in this matter is rapidly being awakened.

DRAINAGE SERVICE.—The interest in reclamation work by drainage continues to develop. During the last year this work has been pushed by the Soils department. Professor Jones has spent a considerable portion of his time in organizing 26 such projects, about one-half of which were on tile drainage, and the remainder open ditch work. The tiling projects have ranged from small tracts of a few acres to areas covering 200 acres; the open ditch work has been done on areas from 200 to 1,000 acres in extent. Preliminary surveys have been made where the necessity for drainage districts was evident, and plans submitted for same.

The Soils department aided in securing an amendment to the drainage law by the last legislature, making it possible to omit one hearing when the preliminary plans are sufficiently developed, thus lessening the expense and time necessary to organize drainage districts. In four cases, Lamartine, Fond du Lac county, Albion and Rutland, in Dane county, and the Larson Drainage District, in Winnebago county, meetings were held at

which plans and cost of proposed work were explained, as well as preparation of proper petitions for organization of such work.

Where tile drainage projects have been located on the farm of a single owner, neighborhood meetings were held to demonstrate the methods applied. Collection of data indicating the benefit to be derived from drainage has been undertaken. Reports indicate that the more thorough systems undertaken at a comparatively high cost are in the end the most satisfactory. The results obtained on a 30-acre marsh at Stoughton have had the effect of increasing the value of undeveloped but available marsh land in that vicinity in some cases as much as $10 per acre.

ORCHARD SPRAYING.—During this year spraying demonstration tests have been continued by Mr. J. G. Milward on orchards located in Sauk, Winnebago and Kewaunee counties, approximately 22 acres being treated. Special effort was made by advertising the fact in the local press, to secure the attendance of persons interested in this line of work at these field meetings, which were held at the time of spraying, and again during the harvesting period. From observations made during this year, it appears that 60 to 90 per cent of all apples grown in the state are infested with the codling moth. Mr. Milward reports the fungus disease, apple scab, to be less prevalent this year than usual, but fully 30 per cent of the apples grown were nevertheless affected.

The results obtained in the orchard spraying work this year have been unusually striking. An average of all orchard work carried out showed about 6 per cent of unsound fruit on trees that had been sprayed with Bordeaux mixture and arsenate of lead, while in the control portion of the orchard that was left untreated about two-thirds of all of the fruit was unsound. A conservative estimate indicates that a net gain of not less than $50 per acre was made on the crop where it was properly sprayed.

POTATO SPRAYING.—The Horticultural department has continued the demonstration work on potato spraying, Mr. Milward having direct charge of the same, as in former years. Spraying demonstrations have been carried on in Waushara, Barron, Washburn and Waupaca counties, 18 acres in all being treated with Bordeaux mixture. At the field meetings, held during the summer, not only was the subject of potato spraying discussed, but all phases of potato culture, seed selection, etc., were considered.

The frost that occurred in the potato districts on August 30

seriously injured the crop and detracted from the success of the work this year, but for a period of 10 days prior to this time, the vines began to show evidence of the blight and a difference in the condition of the sprayed and unsprayed fields was observable. The beneficial results of this spraying work are not to be wholly measured by the mere increase in crop yields as to quantity or quality. Where a man can be induced to take up spraying and carry it on efficiently, his interest in improved methods of culture and general care of his crop is aroused, so that he becomes a much more intelligent student of his business. This improvement in mental attitude is really the more important work of the two.

CRANBERRY SPRAYING.—In connection with the work of the cranberry station at Cranmoor, in Wood county, Mr. O. G. Malde, Superintendent of this Station, has, in conjunction with Mr. C. B. Hardenberg, the federal expert in Entomology, carried on spraying demonstrations in several regions. It is becoming more and more apparent that the insect pests affecting this crop must be controlled. Although the losses from the fruit-worm were unusually small this year, the spraying application reduced them, in some cases, from 12 per cent to about 0.9 per cent. Spraying is found to be especially effective where clean culture is carried on.

In addition to the spraying work, the Station grounds afford a demonstration to those interested in cranberry culture, as to proper methods of handling this intensive industry. The results of the clean culture method have been strikingly successful this year, and much interest has been manifested in the general work of the Station. Mr. Malde's services have been solicited by a number of people who are for the first time taking up cranberry culture. It is gratifying to find that the industry is attracting increased attention and that new projects in other portions of the state are being started in the right way.

CROP DEMONSTRATION FARMS.—In the dissemination of purebred seeds, an effective method has been developed in the establishment of demonstration farms on lands belonging to the various state institutions and the county "poor farms." Thirteen such farms have co-operated with the department of Agronomy during the past year, seven of which were state institutions, such as the state prison, state reformatory, home for the feeble minded, school for dependent children, and the asylums for the

insane. This work has been under the immediate charge of Prof. C. P. Norgord, and has had two definite objects in view,—first, to supply each farm with Station-bred seed, and make it the center of its respective community for the growth and dissemination of high-grade seed grains; second, to put into operation on these farms the most approved methods of crop management so as to demonstrate to neighboring farmers the advantage of such methods. The importance of proper storage of seed corn was effectively shown by testing samples secured from 150 farmers. These were tested as to germination at the Station, and field tests made on the county farms, to determine stand and yield. The results indicated that low germinating corn invariably produces a low stand and a reduced yield.

Meetings were held during the summer on all of these farms, the attendance ranging from 35 to 130, with an average of 60 The comparative demonstration of the superior merits of the best varieties of seeds appears to have been much appreciated. Where such a community center is established, it immediately becomes a center for the dissemination of improved varieties of seeds.

TUBERCULOSIS POST-MORTEM DEMONSTRATIONS.—The educational campaign for arousing interest in the subject of bovine tuberculosis, by making public post-mortems on cattle that have been condemned by the tuberculin test, has been continued by the Station in co-operation with the State Live Stock Sanitary Board. Such demonstrations were held at several of the Farmers' Courses as well as at the state and county fairs. Over 2,000 persons were in attendance at the demonstration held in the new Stock Pavilion at the time of the 10-days' Farmers' Course last February. At Menomonie, the meeting was held in the armory, which was filled. The influence of this graphic method of portraying the ravages of this insidious disease continues to reflect itself in the increased voluntary demand for tuberculin which is supplied by the Board (address, Secretary Live Stock Sanitary Board, Madison, Wis., not the Experiment Station). Last year over 43,000 animals were tested, as reported by that Board.

NORTHERN SUB-STATIONS.—Much of the work of the branch experiment stations which are located in the northern part of the state at Ashland, Iron River, and Superior, is demonstrative in

character. In addition to the purely experimental work which is carried on in these localities, fields are maintained which are designed to show those who visit these stations, the types of grains, fruits, etc., adapted to the region, as well as methods of soil treatment that are recommended.

Year by year, the work of these sub-stations becomes more and more important, and it is now generally acknowledged that they have been instrumental in aiding greatly in the development of this region. Practically all of the settlers who are coming in to develop this forest region confront entirely new conditions, and the experience of the Station is eagerly sought by such individuals as well as by those interested in the sale of lands. Superintendent E. J. Delwiche, who has had immediate charge of this work since it was inaugurated, also holds a number of meetings during the winter, throughout the northern counties, so that the results of the work are given as wide publicity as possible.

When these sub-stations were first established, lands were leased for the purpose rather than purchased outright, as the whole question was somewhat experimental in character. Their success, however, has been so marked that a policy of permanent location should be adopted. The last legislature enacted a law, making possible the establishment of two branch stations, under certain conditions. Arrangements have practically been perfected for the location of one of these at Spooner, Washburn county, immediately contiguous to the city, on sandy jack pine soil. This site is admirably adapted to serve the needs of the extensive region in Burnett, Douglas, Washburn, Sawyer, and Bayfield counties that is more or less covered with this forest growth. The Station is located on a soil that is typical of the entire belt, and is readily accessible by rail and highways. It is hoped that improvement work may be carried on this winter so that some crops may be planted next spring.

GENERAL EXTENTION WORK

DISSEMINATION OF PURE-BRED SEEDS.—The Wisconsin Experiment Association (composed of students who have attended the agricultural courses at the university) still continues to be the most potent factor in the matter of disseminating pure-bred seeds throughout the state. This association now has a paid-up active

membership of 1,255, most of whom are actively engaged in growing and selling pure-bred seed grains. The growth of this organization has been so great that it is difficult now for its officers to give adequate time to the supervision of its work. To overcome this, county orders have been developed in the counties where the membership is the largest (eight are now organized). The officers of the local organization supervise the work in each county. Not infrequently has it been possible for the Agronomy department to send orders amounting to a thousand bushels or more of selected corn or barley to be filled by these local organizations. Large sums of money are now being brought into the state annually because of the active demand for improved seeds of various types.

TOBACCO SEED DISSEMINATION.—Efforts have been made by the Horticultural department for several years to improve the character of the tobacco crop of the state by distributing a selected type of Connecticut-Havana seed leaf tobacco which has been developed with especial reference to the quality of plant produced. Selection of seed was made with reference to size of plant, number, and shape of leaves, as well as curing quality. By means of an air-blast separator, the lighter seed was blown out, leaving only the heavy seed for use. This season 400 pounds of high grade seed, valued at $3,200, has been sent out to 2,150 growers, located in 50 counties of the state. From data collected from the growers, it appears that this type of tobacco is a somewhat better yielder, that the shape of the leaf is preferable to the old types grown, that more leaves are produced to the stalk, and that it cures out better in the shed. At the present time this type has been so widely distributed that it has been decided to discontinue the general dissemination of the same after this coming season.

YOUNG PEOPLE'S SEED GROWING CONTESTS.—The educational work in this direction has been extended this year by introducing barley, as well as corn contests among the young people in the schools. Eleven barley contests and 31 corn tests have been arranged at 35 different county fairs. Selected seed for this purpose has been furnished by the Station, and distributed by the county fair secretary or the county superintendent of schools to the young people of the county, with detailed instructions as to methods of planting, culture, and care of crop. It is surprising

to see how effective these contests are in interesting children in the matter of improved methods of culture. The reflex effect on the parent has also been shown in many instances. The backward condition of the season this year delayed the corn crop materially, so that some of the earlier fairs did not have so large a number of exhibits as would otherwise have been the case, but approximately 4,500 samples of product have so far been submitted.

COMMUNITY LIVE STOCK BREEDING ASSOCIATIONS.—Interest still continues to develop in the matter of organizing co-operative breeding associations, especially with dairy stock. At present 24 such breeders' associations and two agricultural associations have been organized by Prof. G. C. Humphrey in promoting this work with dairy catttle. An example of what has been accomplished in one or two instances is instructive.

The Barron County Holstein-Friesian Breeders' Association organized in January, 1907, with a membership of 30. It now has 96 members, each of whom is pledged to use none but registered Holstein sires. The Waukesha County Guernsey Breeders' Association began in 1906 with six members. It now has a membership of 40. Over 30 pure-bred sires are now in use. The Association has at the present time over 500 head of pure-bred stock and the demand for stock from the Association is much greater than their ability to supply. This phase of community effort is a type of co-operation that has aided much in the development of the dairy industry in this state.

DAIRY TESTS.—The official testing of pure-bred dairy stock for milk production, under the direction of Prof. F. W. Woll, has increased this last year over 14 per cent, aggregating for the fiscal year 1,474 separate tests on 539 animals. Forty-nine breeders have solicited the control of the production of their animals, 12 of whom began the work this year. The expenses of this work are borne by those who participate in the same, but it has a highly beneficial effect on the development of high-grade dairying throughout the state. Of 334 Holstein animals placed on these official tests, all but 13 were admitted to the Advanced Register of the Holstein-Friesian Association in America.

BUTTER AND CHEESE SCORING EXHIBITIONS.—This year marks the second year of this work, during which 115 creameries and 129 cheese factories were added to the list of those who have

sent in their factory products for scoring and criticism. Many of the makers whose product is below standard fail to take advantage of these monthly tests. It is expected that arrangements may be made this coming year with the Dairy Division of the Federal Department of Agriculture to place a field expert on this work, so that it will be possible to visit the factories and thus reach the makers whose product is inferior in quality.

Awards were granted to those whose product was of best quality where they had participated the required number of times. Twenty-five such awards were granted to butter makers for the first year's work, and 53 for the season just closed, while six cheese makers for the first year and 20 for the second also received such recognition.

Eight of the leading dairy states of the union have now followed the lead of Denmark in developing this line of work. Denmark now spends from $10,000 to $15,000 annually in this work to maintain her supremacy in dairying.

WEED ERADICATION.—In considering the resources of the farm, the matter of weeds is often looked upon as trivial, and yet, large areas of many counties in the state are so seriously infested with noxious weeds of various types as to depreciate land values materially. In a census taken last year by Mr. A. L. Stone, it was found that 250 farmers expended about one-half as much on weed eradication as they paid in taxes. Surely an unnecessary tax of this amount is a serious loss.

The iron sulphate treatment has proved successful and thorough application readily destroys wild mustard, but not Canada thistle and quack grass. The manufacturers of this chemical, however, have raised the price so much that it has led to an endeavor to find some substitute. Experiments with common salt seem to show that this comparatively inexpensive agent may be used as successfully and at about one-half the cost.

During the last season, as well as this, experiments were carried on with hemp as an eradicator of Canada thistle. The dense shade cast by this rapidly growing plant smothers all weed growth on the soil, and several trials on fields badly infested with Canada thistle have been successful. This coming season the method will be much more extensively applied before making general recommendations. Two hundred and fifty specimens of weeds were submitted to this division for identification.

SOIL SURVEY.—The soil is the fundamental asset in agriculture. Until recently the importance of this resource has not been generally appreciated by many farmers and the consequence is that in many portions of our country the fertility of cultivated lands is already on the wane. In our own state, this depletion has not been so pronounced; due, fortunately, to the prominence of animal husbandry, but nevertheless signs of such a condition are beginning to show in certain localities. The case is one which already calls for most careful consideration.

Preliminary to any consecutive work in this direction must come a comprehensive soil survey to determine the nature of the problems to be attacked and their location. The legislature responded at the last session to the appeal made for the organization of such a survey and has provided the funds for the purpose. The work is to be carried on under the auspices of the State Geological and Natural History Survey, in co-operation with the College of Agriculture.

INSPECTION AND CONTROL WORK

A number of lines of our Station work are of the nature of inspection and control work. Some of these are in part maintained on the fees prescribed by law as in the licensing of public service stallions and the feed and fertilizer inspection. The nursery and orchard inspection and the seed control are not yet on a self-sustaining basis.

THE LICENSING OF ALL STALLIONS used for public service continues to exert a most wholesome effect on the development of the horse breeding industry of the state. The relative percentage of pure-bred to grade sires is steadily advancing, as is shown by the following data:

	Percentage of sires licensed	
	Pure-bred	Grade
1906–1907	35	65
1907–1908	40	60
1908–1909	42	58

In 37 counties the number of pure-bred stallions has increased and in 40 counties grade sires have decreased in number. The efficacy of this campaign against the scrub stallion could doubtless be increased, if it were possible to provide veterinary supervision of all licensed animals.

The campaign for improvement in the horse industry which Professor Alexander first inaugurated by securing the passage of the original inspection law has been eagerly adopted elsewhere. Fifteen states have now taken up this matter and secured similar legislation, an increase of 10 over the record of the preceding year.

The educational work associated with this inspection has also borne good fruit in our own state. Two years ago 39 county fairs provided classes and premiums for grade stallions, but this year only nine followed the old method of encouraging the showing of grade stock.

The last legislature amended the stallion license law, materially strengthening its features, making a violation of its provisions punishable as a misdemeanor, and placing the duty of prosecution on the county district attorney.

The following financial statement gives the receipts and disbursements of the Department of Horse Breeding for the past fiscal year as required by law.

FINANCIAL STATEMENT, 1908–1909

Receipts		
Balance from the year 1907–1908	$402.58	
Fees, new licenses	988.35	
Renewals	465.00	
Transfers	175.50	
Duplicates	31.00	
Disbursements		
Salaries, including clerk hire	.....	$1,408.43
Traveling expenses	.....	86.98
Postage and stationery	.....	226.65
Printing and supplies	.....	187.14
Balance on hand	.....	153.23
	$2,062.43	$2,062.43

FEED AND FERTILIZER INSPECTION.—This inspection department, under the administration of Professor Woll, continues to grow in scope of work, 218 brands of feeding stuffs and 31 brands of fertilizers having been licensed for sale in 1909. Three inspectors have been regularly maintained in the field, visiting 853 different dealers in 258 different towns, and collecting 436 samples of feed, nearly all of which have been analyzed. The general attitude of the dealers and manufacturers with reference to the operation of the law is much improved over what it was several years ago.

The legislature of 1909 amended the law in several particulars, requiring that guarantees of maximum content of crude fiber must be given, as well as minimum protein and fat content. A change in the enforcement of the law was also made, placing it in the hands of the officers of the Experiment Station rather than with the State Dairy and Food Commission.

The case of infraction of the law which was tried in the municipal court at Antigo, in which the law was sustained which was appealed to the circuit court of the 10th judicial district and later to the supreme court, was dismissed by that tribunal on technical grounds. The beneficial effect of the law on the quality of feed sold is more and more apparent during late years, and has been of great value to the farming interests of the state.

NURSERY INSPECTION.—Seventy-nine nurseries have been officially inspected this last year by representatives of the Horticultural department. This number is somewhat less than for the previous year, due to the fact that a faulty wording of the old law did not make the inspection compulsory. This condition, however, has been remedied through the passage by the legislature of an entirely new inspection law, which provides that not only shall nursery stock be inspected, but cemeteries, parks, and orchards shall be examined as to their freedom from insect and fungus pests. The work of this year indicates the further establishment of the San Jose scale in several new places in the state. It is apparent that this pest can stand the severe winters in this state, even in the interior regions as well as along the Lake Michigan region. The European fruit scale has also been found in a number of cases where stock was imported from outside the state.

SEED INSPECTION.—The recommendation made in the Director's Report last year that the farmers of the state be given protection by the legislature from the indiscriminate sale of farm seeds, received consideration last winter, and led to the passage of a stringent law requiring the branding of all forage and grain seeds as to origin, purity, and germination tests. The law defines what noxious weeds shall be regarded as impurities or adulterations. The Experiment Station is charged with the control and enforcement of the law, which went into operation July 1, 1909.

The execution of this work has been placed in charge of the Agronomy department, and Mr. A. L. Stone has been designated Seed Inspector. From October, 1908, to the end of the fiscal year, 464 seed tests were made. Sixty per cent of these were for farmers, about 30 per cent for wholesale seedsmen, and the remainder for local dealers. Many samples were found to contain noxious weeds in abundance. Both farmers and seedsmen received material benefit by the determination that seed under consideration for purchase was of low vitality.

GENERAL INFORMATION WORK

LECTURES.—The demand on the Agricultural College for help in one capacity or another from all communities of the state is constantly increasing year by year. This is manifested in so many different ways that it is hard to classify the same. Many requests are received for lectures to attend all kinds of meetings, which we are unable to fill. To a limited extent some aid in this direction can be given, but for the most part such tasks fall on individuals who have certain definite teaching duties to perform in connection with the regular class work at the university. It will therefore be readily seen that services requiring absence from such work, even for a day or so, cannot be undertaken, unless arranged for well in advance.

It should be stated that the regular Farmers' courses given at the county agricultural schools and elsewhere in the winter consume considerable time of the regular staff, but the regular class work of the different members of the staff is previously arranged with this in view.

Over 100 lectures and addresses have been given by different members of the staff outside of the regular university work and the farmers' courses held in different portions of the state.

CORRESPONDENCE.—The amount of correspondence connected with the work of this college is rapidly increasing each year. More and more people of all classes are looking to the Station and college for help on all matters in any way relating to agriculture. Very frequently these requests entail considerable search for definite data to answer satisfactorily the matter in question. Even the mechanical work of replying to these inquiries consumes much time. Some 12 stenographers have been required for the work this last year. Nearly 45,000 letters were

written, 23,000 manuscripts, and 102,000 mimeograph sheets of matter were prepared and sent out in compliance with requests. In addition to this personal correspondence bulletins and reports have also been sent out. The constant revision of our general mailing list and the preparation of special lists for special lines of work entails a large amount of work that is not readily recognized.

EXTENSION COURSES

FARMERS' COURSE AT UNIVERSITY.—For six years it has been customary to hold in February at the College of Agriculture a short course of lectures, demonstrations, and exercises, known as the Farmers' Course. The first season this was given, 175 persons were in attendance. This brief course has grown rapidly in popularity until last year over 800 persons registered for this course and about 500 more were in attendance on special courses held simultaneously (The Women's Course for Homemakers and the Special Dairy Course for creamery and cheese factory operators and managers). These meetings are now recognized all over the state as some of the most important agricultural gatherings of the year.

The good results which have come from the work here at the University have led to the development of the same idea in other portions of the state. At Madison we are now reaching directly perhaps five out of a thousand of the farmers of the state. It is possible of course to increase this percentage somewhat, but it has been deemed worth while to make the attempt to carry this type of extension work to the people in other portions of the state who find it inconvenient or impossible to come to the University for this course.

FARMERS' COURSES AT COUNTY AGRICULTURAL SCHOOLS.—The most feasible place for the development of this work is naturally in conjunction with the county agricultural schools that are now being developed throughout the state. Suitable facilities for meetings and demonstrations are there readily provided, the local faculty are in position to push this work among the farmers of the section, and the holding of such a course, participated in by a well-equipped staff from the college and elsewhere, is of material aid to the development of a thorough interest in the work of the local school.

For the last two winter seasons, the regular College staff has attempted to hold such extension courses, in addition to the Farmers' Course at Madison. The success of the experiment showed the advisability of developing this line of work as a regular feature of the agricultural extension service.

During the last winter season, such courses were held at all of the county agricultural schools then in operation. The data as to registration, etc., are shown below.

	Date.	Time of course.	Number registered.	Number counties represented.
Madison, Dane County:		Days.		
Farmers' Course	Feb. 9—19	10	831	59
Special Dairy Course	Feb. 9—16	8	50	28
Women's Course	Feb. 9—13	5	413	39
Menomonie, Dunn County	Jan. 25—30	5	550	13
Marinette, Marinette County	Mar. 9—11	3	500	10
Wausau, Marathon County	Mar. 2— 4	3	325	8
Winneconne, Winnebago County	Feb. 22—26	5	1,078	18
Total registration			3,737	

The establishment of ten such county agricultural schools is now authorized by the legislature, and this coming season similar courses will again be held in the localities where such schools are in actual operation (La Crosse county having been added this past season). By this means three times as many people have been reached as would have been the case if the work had been confined to Madison. The legislative appropriation for agricultural extension specifies that such work may also be carried on at other points in the state not having county agricultural schools, so it becomes possible to organize the work on a much broader basis.

In doing so, special effort will be made not to interfere with the development of the regular Farmers' Institutes, which have been carried on so successfully for the last two decades. The work is differentiated from that given in the Institutes in that it is presented in the form of demonstrations, lantern slide exhibitions, etc., so far as possible, and is given in the larger centers.

FARMERS' INSTITUTES.—The work of the Farmers' Institutes under the direction of Superintendent George McKerrow has been carried along substantially the same lines as in previous

years. This work is maintained by means of an entirely separate fund ($20,000 annually). The methods followed are the outcome of a large experience, and their applicability to Wisconsin conditions has been amply demonstrated. This work begins in December and runs through 20 weeks until March. Six corps of workers (each corps consisting of a conductor and one regular assistant, two corps of cooking demonstrators and 28 special lecturers, making a total of 44 persons, were engaged last season, holding during the winter season 125 institutes and 43 cooking schools in 62 counties. In addition to these, 16 meetings were held in June in the northern part of the state. The total attendance on these meetings aggregated 85,000 people, 60,000 copies of Farmers' Institute Bulletin, No. 23, and 10,000 copies of Farmers' Institute Cook Book, No. 1, were distributed.

Through the medium of these various agencies, supplemented by the aggressive state associations that are concerned in the improvement of general as well as special agricultural conditions, the farming life of the commonwealth is stimulated to an unusual degree. This manifests itself not only in a material way, but also in the intellectual and social progress which come to a people who spend their energies freely but wisely in uplifting themselves in an educational manner.

ACKNOWLEDGMENTS.

The following donations and loans have been received by the Agricultural Experiment Station during the past year.

DONATIONS.

Deming Co., Salem, O., spray fixture cabinet.
Eagan Mfg. Co., La Crosse. Wis., spray material.
F. E. Myers & Bro., Ashland, O., spray nozzles.
Henry Dreer, Philadelphia, Pa., plants.
Sherwin-Williams Co., Chicago, arsenate of lead.
John Van Loon, La Crosse, Wis., six ears blue ribbon corn.
Frank T. Stare, President, Waukesha Canning Co., three bushels peas.
A. G. Weander, Sioux City, Ia., seed tester.
John C. Watson, Rear Admiral U. S. Navy, sample of hemp grown at the Kentucky Experiment station.
Parke-Davis & Co., Detroit, Mich., pure culture bacteria.
Ekenberg Milk Products Co., Cortland, N. Y., 10 pounds powdered milk.
Bucher & Gibbs Plow Co., Canton, O., one cutaway harrow.
German Kali Works, New York, 4,000 pounds potassium sulphate.
Biesanz Lime and Stone Co., Winona, Minn., 2,000 pounds ground limestone.
Prof. A. S. Alexander, Madison, Wis., various anatomical specimens.
Percheron Society of America, Vol. 11 of Studbook.
American Clydesdale Assn., Vol. 31 of Studbook.
American Shire Horse Assn., Vol. 6 of Studbook.
American Breeders & Importers Percheron Registry Co., Vol. 1 of Studbook.
French Coach Horse Registry Co., Vol. 2 of Studbook.
The American Assn. of Importers & Breeders of Belgian Draft Horses, Vol. 2 of Studbook.
The American Registry of Oldenburg Coach Horses, Vol. 1, of Studbook.
National Register of French Draft Horses, Vols. 8, 9 and 10 of Studbook.
American Shetland Society, Vols. 7 and 8 of Studbook.
American Jack Stock Assn., Vols. 4, 5, 6 and 7 of Studbook.
Creamery Pkg. Co., Newton computator.
J. Severt Anderson, Minneapolis, Minn., Simple creamery computator.
A. Jenson Co., Eureka, Cal., Jensen moisture test with scale.
Standard Paper Bottle Co., New York, one doz. pint single service containers; two doz. one-half pint single service containers.
Kenlweld Can Co., Detroit Mich., six non-returnable one pint milk cans.
Chr. Hansen Laboratory, Little Falls, N. Y., samples of culture for starter.
Elov Ericcson, St. Paul, Minn., samples of culture for starter.
Parke Davis, Detroit, Mich., samples of culture for starter.
Marschall Dairy Laboratory, Madison, Wis., samples of culture for starter.
S. G. Kieth, Boston, Mass., samples of culture for starter.
J. I. Case Thresher Co., Racine, Wis., 150 copies Traction Engine Manual.
Creamery Package Mfg. Co., Chicago, Twentieth Century No. 2 milk heater, Farrington Cream Ripener, Boyd Cream Ripener, Wizard Cream Ripener, 300 gal. capacity, three Wizard 24-bottle turbine testers, Twentieth Century 12-bottle hand tester, Victor 24-bottle Turbine tester, 24-bottle tester with electric motor attachment, 12-bottle hand tester. Victor skim milk pasteurizer, Ideal skim milk weigher, Trunnion starter can, Farrington butter moisture test, Farrington, Jr. butter moisture test, Hart 6-bottle casein test and two Wisconsin curd tests.

4

D. H. Burrell Co., Little Falls, N. Y., No. 4 Simplex power cream separator with intermediate, 4-bottle Facile hand tester, 6-bottle hand tester, 24-bottle hand tester, 36-bottle Facile turbine tester, and 24-bottle hand tester.

A. H. Barber Creamery Co., Chicago, No. 6 Simplex churn, No. 2 B. & W. milk heater, B. & W. skim milk pump and weigher, and No. 1 Simplex hand cream separator.

Vermont Farm Machine Co., Bellows Falls, Vt., 20-bottle Turbine tester, No. 2½ U. S. cream separator, 12-bottle hand tester, No. 7 cream separator, 24 bottle Agos tester, No. 6 hand cream separator, and No. 8 hand cream separator.

De Lavel Separator Co., Chicago. Acme cream separator, No. 17 hand cream separator, No. 12 hand cream separator, (No. 15 hand cream separator) and Cut Out hand cream separator.

Sharples Separator Co., Chicago, No. 32 power cream separator with accelerator washer, No. 4 hand cream separator, and No. 6 hand cream separator.

Melchior, Armstrong & Dessau, New York, Perfect Gloria power cream separator.

National Separator Co., Goshen, Ind., hand cream separator.

Burmeister & Wain, Copenhagen, Denmark. Perfect hand cream separator.

Smith Manufacturing Co., Chicago, Ill., Great Western cream separator.

Standard Separator Co., Milwaukee, Wis., Two Champion hand separators.

Sears, Roebuck & Co., Chicago, Economy cream separator.

Empire Separator Co., Bloomfield, N. Y., two hand cream separators.

Currie Hardware Co., Mason City, Ia., two Eclipse moisture ovens.

King & Walker Co., Madison, Wis., high pressure moisture oven.

Perfection Churn Co., Owatonna. Minn., size 4 power churn.

Marshfield Churn Co., Marshfield, Wis., hand churn.

J. Cherry, Cedar Rapids, Ia.. Edward's Mother Culture case with bottles.

Exhaust Steam Purifier Co., Berlin, Wis., steam purifier, pump and tank.

Marschall Dairy Laboratory, Madison, Wis.. two Marschall acid tests.

Fuller & Johnson Co., Madison, Wis., 3½ H. P. gasoline engine, and 2½ H. P. gasoline engine.

Miller Tyson Co., Canton, O., milk heater.

Brillion Iron Works, Brillion, Wis., Junker curd mill.

Albrecht Mfg. Co., Kewaunee, Wis., skim milk and whey pump.

National Wrapping Machine Co., Los Angeles, Cal., butter wrapping machine.

Northern Electric Co., Madison, Wis., 5 H. P. motor.

Gehl Mfg. Co., Milwaukee, Wis., butter printer.

International Construction Co., Chicago. 6-bottle milk filler.

Jensen Mfg. Co., Topeka, Kan., pasteurizer and cooler, and Haughdahl starter can.

McKinnon & Co., Sheboygan Falls, Wis., combination cheese press.

J. E. Egan Mfg. Co., La Crosse, Wis., field sprayer.

Deming Co., Salem, O., century spray pump.

F. E. Meyers & Bro., Ashland, O., O. K. spray pump.

Gould Mfg. Co., Seneca Falls, N. Y., two Pomona spray pumps.

Hurst Mfg. Co., Canton, O., wheelbarrow sprayer.

International Harvester Co., Madison, Wis., one horse-power sprayer.

Morrel & Morley, Benton Harbor, Mich., Eclipse spray pump.

J. H. Robinson & Son, Evansville, Wis., Hereford bull.

Curtis & Son, Poynette, Wis.. Percheron stallion.

Fred Stubley, Black Earth, Wis., Jersey bull.

Ayers Bros., Honey Creek, Wis., Brown Swiss cow.

J. Q. Emery & Son, Edgerton, Wis., Jersey bull.

C. L. Hill, Rosendale, Wis., Guernsey bull.

Avery Mfg. Co., Peoria, Ill., 18 H. P. double cylinder under-mounted steam engine, steam plow, thresher, and water tank.

Bateman Mfg. Co., Grenlock, N. J., potato digger.

International Harvester Co., Madison, Wis., 15 H. P. gasoline traction engine, and two small gasoline engines.

Loudon Machinery Co., Fairfield, Ia., litter carrier, cross draft hay carrier, sling carrier, and straight draft carrier.
Racine Satley Co., Racine, Wis., New Way corn planter.
Badger Harrow Co., Springfield, Ill., spike tooth harrow.
Parlin & Orendorff Co., Canton, Ill., corn planter, gang plow, and 14-inch walking plow.
Lauson Mfg. Co., New Holstein, Wis., a 2 H. P., a 4 H. P. and a 6 H. P. gasoline engines.

EXCHANGES.

The following papers come to the station in exchange for its reports and bulletins. While used by those connected with the Station to learn the expression of agricultural experience and sentiment, they are placed in the library where they can be read and referred to by our agricultural students, and others of the University, as well as visitors.

FOREIGN EXCHANGES.

A Lavoura, Rio de Janeiro, Brazil.
L'Agricoltura Alessandrina, Alessandria, Italy.
L'Agricoltura Moderna, Milan, Italy.
Agricultural Bulletin, Straits Settlement, Singapore, East Indies.
Agricultural Gazette of New South Wales, Sidney, Australia.
Agricultural Journal of the Cape of Good Hope, Cape Town, South Africa.
Agricultural Journal of India, Calcutta.
Agricultural News, Bridgetown, Barbadoes, West Indies.
Boletim de Agricultura, Sao Paulo, Brazil.
Boletim do Instituto Agronomico, Sao Paulo, Brazil.
Bulletin (de l'Administration) de l'Agriculture, Brussels, Belgium.
Bulletin des Seances de la Société Nationale d'Agriculture de France, Paris.
Canadian Dairyman and Farming World, Peterboro, Ont.
Chronique Agricole du Canton du Vaud, Lausanne, Switzerland.
Cold Storage and Ice Trades Review, London, Eng.
Crónica Agrícola, Buenos Aires, Argentina.
Deutsche Landwirtschaftliche Presse, Berlin Germany.
Farmer's Advocate, London, Ontario.
Farmer's Advocate, Winnipeg, Manitoba.
The Field, London, England.
Garden and Field, Adelaide, South Australia.
Irish Farming World, Dublin, Ireland.
Journal für Landwirtschaft, Berlin, Germany.
Journal of the Bath and West of England Society, Bath, England.
Journal of the Board of Agriculture, London, England.
Journal of the British Dairy Farmers' Association, London, England.
Journal of the College of Agriculture, Imperial University, Tokyo, Japan.
Journal of the Department of Agriculture and Technical Instruction for Ireland, Dublin.
Journal of the Department of Agriculture of South Australia, Adelaide, Australia.
Journal of the Department of Agriculture of Victoria, Melbourne, Australia.
Journal of the Department of Agriculture of West Australia, Perth, Australia.
Journal of the Royal Agricultural Society, London, England.
Journal of the Royal Horticultural Society, London, England.
Journal of the Sapporo Agricultural College, Sapporo, Japan.
Kgl. Landtbruks-Akademiens Handlingar och Tidskrift, Stockholm, Sweden.
Landwirtschaftliches Wochenblatt f. Schleswig-Holstein, Kiel, Germany.
Live Stock Journal, London, England.
Mark Lane Express, London, England.

Milch Zeitung, Leipsig, Germany.
Mitteilungen der Deutschen Landwirtschafts-Gesellschaft, Berlin, Germany.
Natal Agricultural Journal, Maritzburg, Natal.
New Zealand Dairyman, Wellington, N. Z.
North British Agriculturist, Edinburgh, Scotland.
Nyt Magazin for Naturvidenskaberne, Kristiana, Norway.
O Criador Paulista, Sao Paulo, Brazil.
O Fazendeiro, Sao Paulo, Brazil.
Queensland Agricultural Journal, Brisbane, Australia.
Rural World, London, England.
Terre Vaudoise, Lausanne, Switzerland.
Tidsskrift for det Norske Landbrug, Christiania, Norway.
Tidsskrift for Landökonomi, Copenhagen, Denmark.
Transactions of the Highland and Agricultural Society of Scotland, Edinburg, Scotland.
Transvaal Agricultural Journal, Pretoria.
Ugeskrift for Landmand, Copenhagen, Denmark.
Weekly Times, Melbourne, Australia.
West Indian Bulletin, Bridgetown, Barbadoes, West Indies.

DOMESTIC EXCHANGES.

Agricultural Student, Columbus, Ohio.
American Agriculturist, New York, N. Y.
American Cultivator, Boston, Mass.
American Fertilizer, Philadelphia, Pa.
American Food Journal, Chicago, Ill.
American Fruits, Chicago, Ill.
American Fruit and Nut Journal, Petersburg, Va.
American Hay, Flour and Feed Journal, New York, N. Y.
American Miller, Chicago, Ill.
American Poultry Advocate, Syracuse, N. Y.
American Sheep Breeder, Chicago, Ill.
American Sugar Industry and Beet Sugar Gazette, Chicago, Ill.
American Swineherd, Chicago, Ill.
American Thresherman, Madison, Wis.
Arboriculture, Connersville, Ind.
Arkansas Homestead, Little Rock.
Baker's Helper, Chicago, Ill.
Berkshire World, Springfield, Ill.
Better Fruit, Hood River, Ore.
Breeder's Gazette, Chicago, Ill.
Bulletin of the National Association of Wool Manufacturers, Boston, Mass.
California Fruit Grower, San Francisco, Cal.
Canadian Horticulturist, Ottawa, Can.
Chicago Daily Drovers' Journal, Chicago, Ill.
Chicago Dairy Produce, Chicago, Ill.
Chicago Live Stock World Chicago, Ill.
Cold Storage and Ice Trade Journal, New York, N. Y.
Colman's Rural World, St. Louis, Mo.
Commercial Poultry, Chicago, Ill.
Cotton Seed, Atlanta, Ga.
Creamery Journal, Waterloo, Iowa.
Dairy Record, St. Paul, Minn.
Dog Fancier, Battle Creek, Mich.
Elgin Dairy Report, Elgin, Ill.
Farm and Fireside, Chicago, Ill.
Farm and Stock, St. Joseph, Mo.
Farm Journal, Philadelphia, Pa.
Farm Life, Chicago, Ill.
Farm Press, Chicago, Ill.
Farm, Stock and Home, Minneapolis, Minn.
Farm World, Augusta, Me.
Farmers' Guide, Huntington, Ind.
Farmer's Messenger, Atlantic, Iowa.
Farmers' Review, Chicago, Ill.
Farmers' Tribune, Sioux City, Iowa.
Farmers' Voice, Chicago, Ill.
Field and Farm, Denver, Colo.
Flour and Feed, Milwaukee, Wis.
Floral Life, New York, N. Y.
Florists' Exchange, New York, N. Y.
Fruit Grower, St. Joseph, Mo.
Gardening, Chicago, Ill.
Gas Power, St. Joe, Mich.
Gas Review, Madison, Wis.
Geflügel Züchter, Wausau, Wis.
Gleanings in Bee Culture, Medina, O.
Green's Fruit Grower, Buffalo, N. Y.
Guernsey Herd Register and Breeders' Journal, Petersboro, N. H.
Hawaiian Forester and Agriculturist, Honolulu.
Hoard's Dairyman, Fort Atkinson, Wis.
Holstein-Friesian Register, Brattleboro, Vt.
Holstein-Friesian World, Ithaca, N. Y.
Homestead, Des Moines, Iowa.
Horse-Shoers' Journal, Detroit, Mich.
Horticulture, Boston, Mass.
Hospodar, Omaha, Neb.

Hospodårske Listy, Chicago, Ill.
Illuminated World Life, Minneapolis, Minn.
Independent Farmer and Western Swine Breeder, Lincoln, Neb.
Indian School Journal, Chilocco, Okla.
Indiana Farmer, Indianapolis, Ind.
Iowa State Register and Farmer, Des Moines, Iowa.
Irrigation Age, Chicago, Ill.
Jersey Bulletin, Indianapolis, Ind.
Kansas Farmer, Topeka, Kan.
Kimball's Dairy Farmer, Waterloo, Iowa.
Lincoln Free Press, Lincoln, Neb.
Live Stock Journal, Chicago, Ill.
Louisiana Planter, New Orleans, La.
Metropolitan and Rural Home, New York, N. Y.
Michigan Farmer, Detroit, Mich.
Minnesota and Dakota Farmer, Brookings, S. Dak.
Minnesota Farm Review, St. Anthony Park, Minn.
Minnesota Horticulturist, Minneapolis, Minn.
Missouri Agricultural College Farmer, Columbia.
Missouri Valley Veterinary Bulletin, Topeka, Kan.
Modern Farming, Richmond, Va.
National Farmer, Winona, Minn.
National Farmer and Stock Grower, St. Louis, Mo.
National Fruit Grower, St. Joseph, Mich.
National Grange, Concord, N. H.
National Monthly Farm Press, Chicago, Ill.
National Swine Magazine, Freeport, Ill.
Nebraska Farmer, Omaha, Neb.
New York Produce Review and American Creamery, New York, N. Y.
North Carolina Student Farmer, West Raleigh.
Northwest Horticulturist, Tacoma, Wash.
Northwestern Agriculturist, Minneapolis, Minn.
Nut Grower, Poulan, Ga.
Ohio Farmer, Cleveland, Ohio.
Oklahoma Farm Journal, Oklahoma City.
Orange Judd Farmer, Chicago, Ill.
Oregon Agriculturist, Portland, Ore.
Pacific Dairy Review, San Francisco, Cal.
Pacific Fruit World, Los Angeles, Cal.
Pacific Rural Press, San Francisco, Cal.
Philippine Agricultural Review, Manila.
Poultry Digest, New York, N. Y.
Practical Dairyman, Rutherford, N. J.
Practical Farmer, Philadelphia, Penn.
Profitable Poultry, Milton, Wis.
Pure Products, New York, N. Y.
Reliable Poultry Journal, Quincy, Ill.
Rock Products, Chicago, Ill.
Rural Press, Chicago, Ill.
Shepherd's Journal, Chicago, Ill.
Southern Fruit Grower, Chattanooga, Tenn.
Southern Planter, Richmond, Va.
Southwestern Farmer and Breeder, North Fort Worth, Texas.
Student Farmer, Madison, Wis.
Successful Farming, Des Moines, Iowa.
Successful Poultry Journal, Chicago. Ill.
Sugar Beet, Philadelphia, Pa.
Texas Farmer, Dallas, Tex.
Town and County Journal, San Francisco, Cal.
Trade, Baltimore, Md.
Thresherman's Review, St. Joe, Mich.
Twentieth Century Farmer, Omaha, Neb.
Wallace's Farmer, Des Moines, Iowa.
Western Empire, Los Angeles, Cal.
Wilson Bulletin, Oberlin, Ohio.
Wisconsin Agriculturist, Racine, Wis
Wisconsin E [illegible]ty News, Madison, Wis.
Wisconsin Farmer, Madison, Wis.
Wisconsin Sugar Beet, Menomonee Falls, Wis.

FINANCIAL STATEMENT.

The Wisconsin Agricultural Experiment Station, in account with the United States appropriation.

1908-1909.	Dr.	Cr.
To receipt from Treasurer of the United States as per appropriations for the year ending June 30, 1909, under the acts of congress approved March 2, 1887, and March 16, 1906	$26,000 00	....
By salaries	....	$14,780 00
By labor	....	2,695 70
By publications	....	22 75
By postage and stationery	....	204 98
By freight and express	....	29 84
By heat, light and water	....	73 80
By chemical supplies	....	839 55
By seeds, plants and sundry supplies	....	1,441 21
By fertilizers	....	41 21
By feeding stuffs	....	2,457 89
By library	....	464 68
By tools, implements and machinery	....	678 24
By furniture and fixtures	....	161 00
By scientific apparatus	....	503 32
By live stock	....	564 00
By traveling expenses	....	737 19
By contingent expenses	....	15 00
By building and repairs	....	289 69
	$26,000 00	$26,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Wisconsin Agricultural Experiment Station for the fiscal year ending June 30, 1909; that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $26,000, and the corresponding disbursements $26,000, for all of which proper vouchers are on file and have been by us examined and found correct.

And we further certify that the expenditures have been solely for the purpose set forth in the acts of Congress approved March 2, 1887, and March 16, 1906.

M. SWENSON, Chairman,
L. S. HANKS,
PLINY NORCROSS,
Executive Committee.

ATTEST.
M. E. MCCAFFERY,
Secretary.

PART II

RESEARCH BULLETINS

The Rôle of Inorganic Phosphorus in the Nutrition of Animals

E. B. HART, E. V. McCOLLUM AND J. G. FULLER.

The importance of the ash constituents of various food stuffs for the maintenance of a normal condition of health in man is indicated by the disturbances which followed all attempts of various observers[1] to subsist any length of time on an ash free diet. Forster's[2] experiments on dogs and pigeons with a diet composed of ash free carbohydrates and fats and of meats containing only a small amount of salt, point to the same conclusion. Lunnin's[3] experiments with mice, somewhat modified to overcome the acidity resulting from protein sulphur metabolism by addition of carbonate of soda, but with the other essential ash constituents missing, likewise failed to sustain these animals.

The recognition by Bunge of the relationship between the ash content of milk and the time required to double the weight of new born animals of various species, is in this connection extremely interesting. For example, the required time for doubling the weight in the following species: man, horse, cow and dog, is respectively 180, 60, 47, and 9 days. The percentage of ash in the milk of these different animals in the order named is 0.22, .41, .80 and 1.31. From this he arrives at the conclusion that the more rapidly the suckling grows the greater the needs of the organism for those food stuffs which serve for the building up of the tissues, namely, proteins and salts. These experiments and our general understanding from other lines of

[1] Taylor, Studies on an Ash-free Diet, Pub. Univ. of Cal., Path., 1904, 1:71.
[2] Zeit. fur Biol. 9:297.
[3] Zeit. Physiol. Chem. 10:31.

inquiry of the part played by the ash constituents in intestinal digestion and absorption of proteins and fats, in favoring the action of ferments in intracellular proteolysis and lipolysis and the accelerating action of various alkaline salts on the conduct of carbohydrates and various other organic complexes, to say nothing of the development of skeletal tissues rich in calcium phosphates, only emphasizes the important rôle played by the mineral constituents of the body in the absorption and metabolism of food and in body growth.

The practical significance of this subject of the relation of ash constituents of feeding stuffs to animal nutrition has very lately received direct comment.[4]

It has been observed that some of the locally grown feeding materials on the Hawaiian Islands especially the forage crops, are deficient in lime. This is attributed to the fact that they were grown on volcanic soils. Animals receiving such feeding materials failed to make good growth and their yield of milk was unsatisfactory.

Investigations in the Transvaal[5] on certain locally grown feeding materials have also demonstrated that these materials show a deficiency of calcium in proportion to phosphoric acid and to this deficiency has been attributed a lack of thrift and other unfavorable symptoms with horses and mules receiving these feeding materials.

Considerable attention both in this country[6] and abroad,[7] has been devoted to the problem of supplementing certain feeding materials either with complex ash mixtures, such as wood ash, or with more limited definite salts such as the calcium phosphates. These efforts have been undertaken either in the hope of finding suitable agents for combating the pathological condition known as rickets, or in aiding the development of body tissues in young and growing animals receiving rations believed to be deficient in the necessary ash constituents.

In the case of rickets the evidence seems to support the contention that calcium phosphate is a useful supplement to the diet, but it is still an open question whether this salt subserves

[4] Expt. Sta. Rec. 1908, **19**:803.
[5] H. Ingle, Jour. Compar. Path. and Ther., 1907, **20**:35.
[6] Henry, Wis. Agr. Expt. Sta. 6th Ann. Rpt. 1889, p. 15.
[7] N. Schenke, Landw. Vers. Stat., 1903, **58**:19.

a useful function when added to the ration of normal food materials.

Again, in experiments where but a single grain has been used, such as corn, supplemented with ash materials for the nutrition of growing swine, no consideration has been given to the limiting power of the organic nutrients from a single source for the complete and normal development of the animal. This factor, as well as the limitation and relative proportions of ash constituents in a ration, must be given careful consideration by students of nutrition.

Our problem was to determine whether inorganic phosphates such as di- and tri-calcium phosphates, could take the place of organic forms of phosphorus in a ration for growing swine. The growing young, in its rapid cell expansion and consequent increasing nuclei formation, with an accompanying increase of nucleins and nucleo-proteids, presents admirable advantages for such studies. It is apparent that if such a fundamental process as nucleo-proteid and phosphatide formation in the animal body is a chain of syntheses, involving an inorganic form of phosphorus, then the comparative values of forms of phosphorus contained in the ration, be they lecithins, nucleins, phytates or inorganic phosphates, in so far as they are carriers of phosphorus, becomes a matter of secondary importance. Whatever special influence they might exert would then more properly lie in the nature of the non-phosphorus group to which the phosphorus group is attached. It would extend the already widely established range of synthetic processes in the animal cell.

Rohmann[8] and his pupils have reached the conclusion that the animal organism has not the power to synthesize organic phosphorus combinations from phosphorus-free proteids and mineral phosphates, while Keller[9] and Ehrström[10] have deduced quite contrary conclusions from their own observations and have given to the inorganic phosphates a place in the synthesis of nucleo-proteids by the animal cell.

While our experiments would throw light on the above prob-

[8] Berlin. Klin. Wchnschr., 1898.
[9] Arch. fur Kinderheilk., 1900.
[10] Skand. Arch. Physiol., Bd. 14.

lem of nucleo synthesis they would also aid in reaching conclusions on the fate of supplemented calcium phosphates in a low phosphorus ration.

Already numerous experiments on the use of phosphates and other ash materials as supplements to rations have been undertaken. Kohler[11] in experiments with lambs found that calcium and phosphoric acid were more thoroughly assimilated in the form of precipitated calcium phosphate, which is a mixture of tri- and di-calcium phosphates. Hoppe-Seyler[12] found that calcium phosphate was absorbed from the digestive tract of man and the experiments of Gohren,[13] Lehmann[14] and Weildt[15] point to similar results with small animals.

The evidence as to the benefits derived from the use of inorganic phosphates when fed to sound animals is contradictory. Cohn[16] reports observations on the addition of calcium phosphate to the food of calves and pigs where no apparent influence was exerted, while a marked benefit was observed in experiments with two or three year old horses. Hofmeister[17] failed to receive beneficial returns from the use of precipitated calcium phosphate with three months' old lambs. Heiden[18] observed an increased weight and a general beneficial influence from the addition of 25 grams of calcium phosphate to the daily food of weak pigs, but when stronger animals were used no influence was evident.

Hess and Schaffer[19] report that when 50 grams of calcium phosphate were added to the daily food of four cows, the milk contained an increased proportion of that compound and these experiments are supported by Passon,[20] who emphasizes this as of importance in enriching the mother's milk in calcium phosphates.

Experiments at Mockern[21] indicate most beneficial results

---

[11] Ztschr. Untersuch. Nahr. u. Genussmtl., 1904, 8:683.
[12] Med. Chem. Untersuch., Heft 2.
[13] Landw. Vers. Stat., 1861, 3:161.
[14] Jahresber. Agr. Chem., 1876, 16:183.
[15] Jour. Landw. 1874, 22:1.
[16] Landw. Vers. Stat., 1873, p. 123.
[17] Ibid., p. 126.
[18] Jahresber. Agr. Chem., 1874, 16:62.
[19] Landw. Jahrb. Schweiz., 1891, 5:76.
[20] Jour. Landw., 1905, 53:113.
[21] Landw. Vers. Stat., 1902, 57:239.

from the use of 30 to 50 grams of calcium phosphate in the daily ration of steers which had shown marked brittleness of bones, caused by administering a ration low in phosphates. H. D'Auchald[22] found an increased weight of the skeleton of chickens which were fed a ration containing four grams of added bone when compared with those not receiving this addition, and Wheeler[23] has observed that the addition of bone ash improves most grain rations as food for young chicks.

Kohler[24] has lately compared the assimilability of different forms of calcium phosphate by lambs and has given to di-calcium phosphate a value four times greater than that of bone ash. H. Labbe[25] mentions the faulty assimilation of inorganic phosphorus compounds and obtained much more favorable results with such organic forms as nucleins and lecithins. Desgrez and Zaky[26] have noted marked gain in weight when guinea pigs were fed with an added quantity of lecithins and nucleins, and the work of Gilbert and Fournier[27] lead to similar conclusions from their experiments on young dogs.

RESULTS OF PREVIOUS INVESTIGATIONS.

A summary of definite conclusions from the evidence given in the literature quoted would be a difficult matter. However, it appears to be well established:

1. That added ash constituents are absorbed from the digestive tract.

2. That animals receiving rations somewhat low in calcium and phosphorus or these elements in improper proportions with brittle bones as the result, do absorb added calcium phosphates with remedial effect.

3. That even with normal rations, added calcium phosphate is absorbed with increased bone formation.

Some of the questions still in contradiction or totally uninvestigated in this matter are:

1. How far must the ash ingredients be in organic combinations to be of nutritive value:

[22] Jour. Agr. Prat. n. ser. 7, 1904.
[23] N. Y. Agr. Expt. Sta. Bul. No. 242.
[24] Ztschr. Untersuch. Nahr. u. Genussmtl., 1904, 8:683.
[25] Brit. Med. Jour., 1904, No. 2267.
[26] Compt. Rend. Soc. Biol., Paris, 1904, 57.
[27] Ibid., 1900, 53:145.

2. What is the relative value of the form of the ash constituent in the ingested food, for the formation of specific bodies in important secretions rich in these ash constituents;

3. What are the minimum limits of ash constituents for normal vigorous development;

4. What is the influence of the proportion of base to acid forming constituents of the ash on metabolism;

5. Can an excess of ash constituents in the food materially influence the ash constituents of specific secretions like milk.

In a previous publication[28] it has been shown that when the phosphorus content of a ration in the form of phytin was raised from 22 to 77 grams per day, the phosphorus content of cow's milk was not appreciably affected. The experiment of Hess and Schaffer already cited, on the same class of animals, where calcium phosphate was the form used, furnishes quite different conclusions.

The problem which we have undertaken concerned itself primarily with the study of the limiting power of the animal organism to supplement inorganic phosphates for organic forms of phosphorus in its growth. It was believed that such studies would throw light on the synthetic limitations of the animal cell in so far as the forms of raw material for nucleoproteid building were concerned, and the question of how far phosphates added to a ration deficient in such ash materials, could be utilized. It was believed that if it could be established that a ration so low in phosphorus as to retard normal development and induce pathological symptoms in young animals could produce normal development when fortified with calcium phosphate, or with organic forms of phosphorus such as phytin, it would aid in giving a definite solution to our problem.

PLAN OF THE INVESTIGATION.

Our studies for the last two years have been conducted with young growing pigs, and have been arranged in accordance with the following plan:

1. Several lots of pigs were to be fed over long periods of time, rations differing greatly in the form of phosphorus which

[28] N. Y. Agr. Expt. Sta. Tech. Bul. No. 1.

they supplied; the quantity of phosphorus furnished to be as nearly equal in all cases as possible.

2. One lot, to be designated the "basal" lot, was to receive as low a phosphorus ration as it was possible to prepare.

3. Another lot, to be designated the "standard" lot, was to receive a mixture of normal feeds, carrying a variety of forms of phosphorus.

4. The other lots were to receive a basal ration, fortified with the forms of phosphorus whose influence it was desired to study.

5. All rations were to be maintained on the same nutritive plane as far as our knowledge would permit.

6. Composition of the feeds was to be accurately known.

7. In a limited number of cases the rations were to be carefully sampled and weighed and the excreta quantitatively collected.

8. The weight of the animals was to be taken periodically.

9. After continued feeding over a long period of time, the tissues of the animals were to be subjected to such chemical examinations as were essential to the elucidation of the problem.

It was hoped that this plan would furnish data on:

1. The comparative value of certain forms of phosphorus bearing bodies for the young growing animal.

2. The nutritive value of inorganic phosphates when added to rations low in phosphates.

3. The fundamental processes of organic phosphorus building in the animal body.

4. The influence of phosphorus starvation on the composition of the tissues and the physical condition of the animals.

5. The minimum phosphorus requirement of young growing pigs.

EXPERIMENT I.

THE RATIONS.—It was necessary to provide a ration as low in phosphorus as possible. This was secured by the use of rice, wheat gluten, and washed bran. This gave us our basal ration, to which was added the form of inorganic phosphorus, to be tested. When the washed bran was substituted directly by wheat bran, we had under experiment the organic form of phosphorus, phytin, removed by washing whole wheat bran. The washed wheat bran was obtained from whole bran by al-

lowing the latter to soak over night in warm water, when an acid fermentation resulted. The bran was subsequently thoroughly washed with water and dried. The removal of phytin from the bran not only lowered the phosphorus content of the bran, but also lowered the magnesium and potassium content. These losses were returned to the basal ration by the proper addition of a mixture of 200 grams of cane sugar and 100 grams each of sodium chloride, magnesia chloride, and potassium sulphate. The proportion of these mixtures added to the daily ration will be indicated later.

Five lots of pigs were used. Lot 1 received the basal ration. Lots 2 and 3 received the basal ration, and in addition different amounts of precipitated calcium phosphate, lot 2 receiving about 40 grams per pig, and lot 3 about 20 grams per pig daily. The precipitated phosphate used was shown to consist of a mixture of 70 per cent di-calcium phosphate and 30 per cent tri-calcium phosphate. Lot 4 received a ration composed of rice, wheat gluten, and whole bran. This supplied phosphorus, magnesium, and potassium in the organic complex, phytin. Lot 5 was fed a standard ration for growing pigs, consisting of corn, oats, wheat middlings, and oil meal, and which furnished a variety of forms of phosphorus.

The different feeds comprising the basal ration were selected because they had as low a phosphorus content as any fairly palatable feeds which could possibly be used. Through the use of wheat gluten with a protein content of 70 to 75 per cent, it was easy to regulate the protein supply of the ration, and at the same time hold the phosphorus content to a low limit.

THE EXPERIMENTAL ANIMALS.—Sixteen vigorous young pigs of mixed breeding were used in the experiment. All males were castrated. The pigs were divided into five lots, with as equal a total weight for the first four lots as it was possible to secure. The average weight of the pigs in all lots was 47 pounds. At the beginning of the experiment they were in fair flesh, apparently healthy and vigorous.

MANAGEMENT OF THE EXPERIMENT.—The animals were confined within the hog barn during the entire experiment. Each lot had a sleeping pen, floored with wood, and a feeding pen directly across the passage way from the sleeping pen. All pens were bedded with pine wood shavings. This the animals

fortunately did not eat, thereby introducing no vitiating factors in the intake of phosphorus.

Feeds were mixed weekly. This was very carefully done, in order to make the daily ration as constant as possible. The animals were fed twice daily. The different rations were weighed, placed in the respective feeding troughs and enough warm water added to make a moderately thick slop.

A preliminary feeding period of two weeks preceded the actual initial date of the experiment. This was done in order to gradually accustom the animals to the rather severe ration. All were allowed equal amounts daily. During the course of the experiment, as the pigs required it, the amounts of the different rations were gradually increased. At all times care was taken to give only those quantities which would be entirely consumed. The animals were weighed individually once a week at a definite time.

METHODS OF ANALYSES.—Such analytical data as were required were collected on a carefully selected sample of the feeding materials, or on selected parts of the slaughtered animal at the termination of the experiment. The methods of the A. O. A. C. were generally used. Where analyses of any organs were made, they were sparingly washed with water immediately after the slaughter in order to free them from any external blood The extraneous fat was carefully removed and the part finely cut up and dried in a steam oven at 100 degrees C.

PREPARATION OF THE SKELETON.—The bones were carefully scraped as free from meat as possible, stirred in hot water for a short time, to further facilitate complete removal of meat, and dried at 60 degrees C. After the above treatment all determinations of ash were made on the air dried bones.

SEQUENCE OF FEEDING.—Feeding began November 29, 1906. A preliminary period of about two weeks was consumed in initiating the final ration. This was reached December 15. The final mixture of feed that appeared best adapted for this work and would furnish a proper supply of nutrients consisted of 28½ pounds of ground rice, 6 pounds of wheat gluten, and 15 pounds of bran, either washed or whole, as the case demanded. To this amount of feed mixture was added 500 grams of a mixture of 200 grams of sugar, 100 grams each of sodium chloride, magnesium chloride, and potassium sulphate, respect-

ively. It is remarkable to what a high degree of palatability the ration was brought by the salt mixture addition. It was impossible to secure a proper food consumption until this addition was made. The effect of the salt mixtures was to induce a vigorous, keen appetite and cessation of all difficulties in the consumption of the ration.

Where phosphates were being studied, 420 and 840 grams respectively of precipitated calcium phosphate were added to the above quantities of the washed bran ration.

The initial consumption per pig was about $2\frac{1}{5}$ pounds per day. This was increased as the animals demanded it until March 1 the average consumption of all animals, except those receiving the basal and standard rations, was approximately 3 pounds per day. The pigs receiving the basal ration did not increase their food consumption appreciably above the initial amount. The lot receiving the standard ration consumed at this date, March 1, $3\frac{1}{3}$ pounds daily per pig. The experiment covered 95 days.

The tables that follow are condensed from a considerable body of data, and were limited to those which are essential to an analysis of our conclusions.

Table I. Composition of feeding materials used.

Table II. Initial ration of each lot, including daily intake of total phosphorus.

Table III. Total average gain in weight of each lot.

Table IV. Percentage of solids in several important tissues of representative animals from each lot at the end of the experiment.

Table V. Calcium and phosphorus content of several parts of the animal.

Table VI. Dry weight of the skeleton and breaking strength of the thigh bones.

Table VII. Ash content of corresponding bones of the several slaughtered animals.

TABLE I.—COMPOSITION OF FEEDING MATERIALS USED.

Feed.	Water.	Protein.	Fat.	Phosphorus.
	Per cent.	Per cent.	Per cent.	Per cent.
Rice	13.50	8.30	0.35	0.100
Wheat Gluten	7.50	73.50	1.50	.205
Washed Bran	7.40	12.14	4.	.110
Whole Bran	10.90	14.60	4.50	1.51
Corn[1]	10.6	10.3	5.	.313
Oats[1]	11.	11.8	5.	.355
Middlings[1]	12.1	15.6	4.	.87
Oil Meal[1]	10.1	33.2	3.	.789
Calcium Phosphate				15.75

[1]Henry "Feeds and Feeding.." Average Composition of American Feeding Stuffs

TABLE II.—INITIAL RATION OF EACH LOT, INCLUDING DAILY INTAKE OF TOTAL PHOSPHORUS.

	Feeds.	Amount per pig daily.	Total phosphorus.
		Pounds.	Grams.
Lot 1	Ground Rice	1.24	0.56
	Washed Bran	.65	.32
	Wheat Gluten	.26	.24
	Sugar—Salt Mixture	.048	.00
	Total	**2.20**	**1.12**
Lot 2	Ground Rice	1.20	0.54
	Washed Bran	.63	.30
	Wheat Gluten	.25	.23
	Sugar—Salt Mixture	.046	.00
	Calcium Phosphate	.077	5.50
	Total	**2.203**	**6.57**
Lot 3	Ground Rice	1.22	0.55
	Washed Bran	.64	.30
	Wheat Gluten	.26	.24
	Sugar—Salt Mixture	.047	.00
	Calcium Phosphate	.038	2.75
	Total	**2.205**	**3.84**
Lot 4	Ground Rice	1.26	0.57
	Whole Bran	.67	4.59
	Wheat Gluten	.27	.24
	Total	**2.20**	**5.40**
Lot 5	Ground Corn	0.67	0.95
	Ground Oats	.67	1.07
	Wheat Middlings	.67	2.64
	Oil Meal	.22	.79
	Total	**2.23**	**5.45**

TABLE III.—TOTAL AVERAGE GAINS IN WEIGHT OF EACH LOT.

	Number of animal.	Weight Dec. 15.	Weight Mar. 20.	Gain.	Average Gain.
Lot 1	409 410 411	50 45.5 54	85 65.5 84	35 20 30	28.33
Lot 2	402 403 404	51.5 40.5 73	130 61 132	78.5 21.5 59	52.6
Lot 3	406 408 416	39 64 62	78 123 122	39 59 60	52.6
Lot 4	401 405 412	40 47.5 47.5	114 100 102	70 52.5 54.5	59
Lot 5	407 413 414 415	39 65 49 65	78 138 110 138	39 73 61 73	61.5

TABLE IV.—PER CENT OF SOLIDS IN PARTS OF ANIMAL DRIED AT 100 DEGREES C FOR FIVE HOURS.—1907.

PART.	LOT.			
	1. Basal.	2. Phosphate.	3. Whole Bran.	4. Standard.
	Percent.	Percent.	Percent.	Percent.
Number of animal	411.	408.	412.	415.
Kidney	20.38	17.5	17.3	17.
Pancreas	37.7	40.8	33.9	32.
Heart	20.5	23.1	21.4	22.9
Brain	20.4	21.6	18.2	22.1
Blood	21.1	18.7	22.1	14.2
Liver	27.2	29.6	27.9	31.6
Ovaries	16.2	16.7	17.	15.2
Spleen	21.4	21.8	24.5	21.1
Leg Muscle	23.8	25.	28.3	27.1
Tenderloin	24.2	24.	25.9	24.1

TABLE V.—COMPOSITION OF PARTS OF PIGS, AIR DRY.

LOT.	COMPOSITION IN PERCENT.									
	Bone Ash.		Blood.		Leg Muscle		Liver.		Brain.	
	P.	Ca.	P.	Ca.	P.	Ca.	P.	Ca.	P.	Ca.
1. Basal............ No. 411.	18.48	37.16	0.24	0.035	0.93 .90	......	1.43	0.0 0	1.49	......
2. Phosphate...... No. 408.	18.26	36.91	.31	.031	.81 .78	......	1.34	.030	1.57	......
3. Whole Bran...... No. 412.	18.00	37.12	.33	.038	.77 .75	......	1.35	.066	1.54	......
4. Standard.......... No. 415.	18.20	37.23	...... .28	.025	.78 .77	......	...... 1.27	.030	...... 1.43	......

TABLE VI.—DRY WEIGHT OF SKELETONS AND BREAKING STRENGTH OF THIGH BONES.

	LOT.			
	Basal No. 411.	Phosphate No. 408.	Whole bran No. 412.	Standard No. 415.
Weight of skeleton, grams.......	1,193	2.371	1,288	1,609
Weight of animals, pounds.......	84	123	102	138
Breaking strength of thigh one pounds per square millimeter..	0.63	1.80	1.84	1.69
Diameter, millimeters...........	18.	23.9	18.5	22.

TABLE VII.—SPECIFIC GRAVITY AND ASH CONTENT OF CORRESPONDING BONES OF THE SEVERAL SLAUGHTERED ANIMALS.

	LOT.			
	Basal No. 411.	Phosphate No. 408.	Whole bran No. 412.	Standard No. 415.
Specific gravity bones............	0.977	1.157	1.100	1,192
Ash (thigh bone) per cent........	31.	55.	53.	46.

DISCUSSION OF THE DATA FROM EXPERIMENT I.

The discussion to follow can best be given by a consideration of the separate history of each lot. Throughout the experiment it was attempted to hold the amounts of digestible organic nutrients as nearly alike in all the rations as possible. Their character in the standard ration, as compared with the other rations, may have materially differed.

LOT 1, BASAL.—The intake of phosphorus in the basal ration was reduced to 1.12 grams per pig daily, when the consumption was 2.2 pounds of feed. This was as low as it was practicable to prepare considerable quantities of feeding material. The phosphorus in this ration was wholly of an organic type, including nucleins, lecithins, and probably traces of phytates.

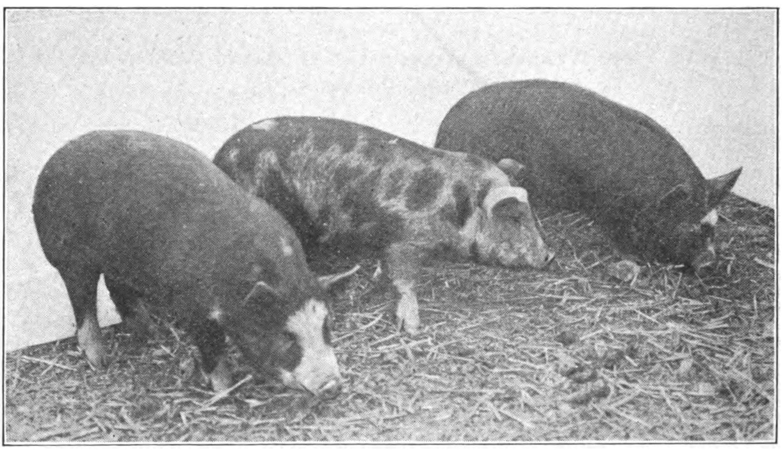


Figure 1. Lot I, basal, at beginning of experiment showing type of animals selected for the experiment.

At the beginning of the experiment, December 15, it was found that the addition of the sugar-salt mixture greatly enhanced the appetite of the animal and aided in creating a relish for this feed. After a few weeks, however, their appetites showed signs of languishing, with a decreased activity of the animals themselves, as compared with the animals of all other lots.

A great deal of time was necessary for the consumption of the daily ration. These conditions manifested themselves more

and more as the experiment progressed. It became the habit of the animals to confine themselves to their sleeping pens in a lying posture from meal to meal. By January 17, one of the animals showed stiffness of the hind legs and a partial loss of

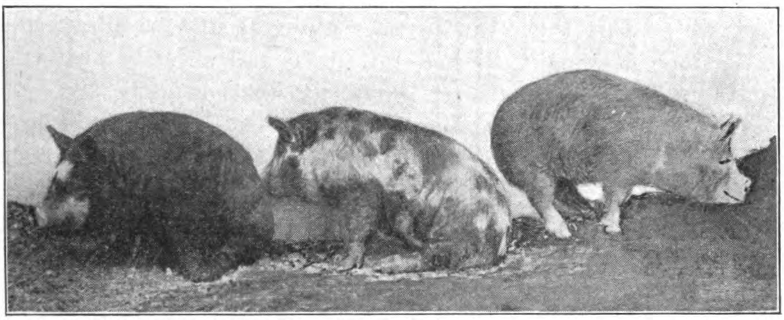


Figure 2. Lot I, basal, at middle of experiment showing effect of a low phosphorus ration as indicated by stiffness of hind legs and partial loss of their control.

their control. A few days later the other animals of the same lot manifested similar symptoms. In no other particular were the animals visibly affected. They continued to gain in weight. These attacks of weakness of limbs and stupor would disappear after a few days, to again return for a more prolonged period. The periods of attack and partial recovery alternated in this

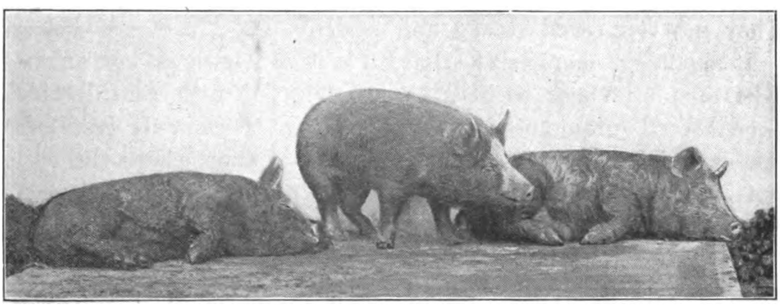


Figure 3. Lot I, basal, at end of experiment showing the stupid and weak condition of the animals, which finally made it necessary to abandon them for experimental purposes.

manner during the experiment. By the end of January it became necessary to assist the animals to their feeding troughs. Their appetites were poor. They continued to lie in a dormant, stupefied condition a large share of the time. Excitability was at a low ebb. When standing, the hind limbs assumed an oblique position, the hind feet resting far beneath

the body and near the fore feet. When in this position, they would slowly lift one foot from the floor, drawing the leg toward the body to again relax the contracted limb. About February 12, one animal in this lot entirely lost the power of sustaining its hind quarters. The fact is worthy of special notice, that, up to this time, the animals receiving the basal ration had gained in weight, showed fair flesh, and a fairly healthy external appearance, although physically weakened.

By March 12, all animals in the lot were in a low state of vitality. Loss of weight had begun and very little feed was consumed; they were induced to move with the greatest difficulty, and apparently with pain. By March 20 the animals were so weak that further continuance of the experiment was abandoned. One animal from the lot was killed and an effort to restore to health the two remaining animals was made. It was planned to restore the debilitated animals by supplementing the basal ration in the one case with organic phosphorus, and in the other with inorganic phosphates. However, the pigs were in such a weakened condition that a more palatable ration had to be given. Milk and wheat middlings were used, with immediate results. Rapid improvements resulted, and on June 8, after a lapse of nearly three months, these two animals, numbers 409 and 410, weighed 150 and 125 pounds respectively, showing gains of 65 and 59½ pounds after their recovery. They now appeared strong and healthy.

It should be emphasized that on a ration with as low an intake of phosphorus as 1.12 grams daily, it took considerable time before pronounced weakness in these animals resulted. An experiment over a shorter duration of time where the animals are merely gaining weight is too often construed as evidence that the animal is receiving proper feeding materials.

The proportion of dry matter in various parts of the animal does not indicate that they differ materially from corresponding parts of animals receiving normal foods.

The proportion of calcium and phosphorus in important tissues of this animal likewise showed no marked variation from corresponding tissues of normally fed animals, or from animals receiving the basal ration, supplemented with inorganic phosphates.

The size and especially the texture of the bones showed a decided variation from those of animals from the other lots.

They were spongy and loose in texture. When broken they appeared honey-combed almost to the outer surface. It appeared to be an extreme case of osteoporosis. Their breaking strength per millimeter was practically but one-third that of the corresponding bones from the animals of all other lots. The specific gravity of the bones was less than one, while in all other lots it was greater than one. Further, and of greatest significance, there was but 31 per cent of ash in the thigh

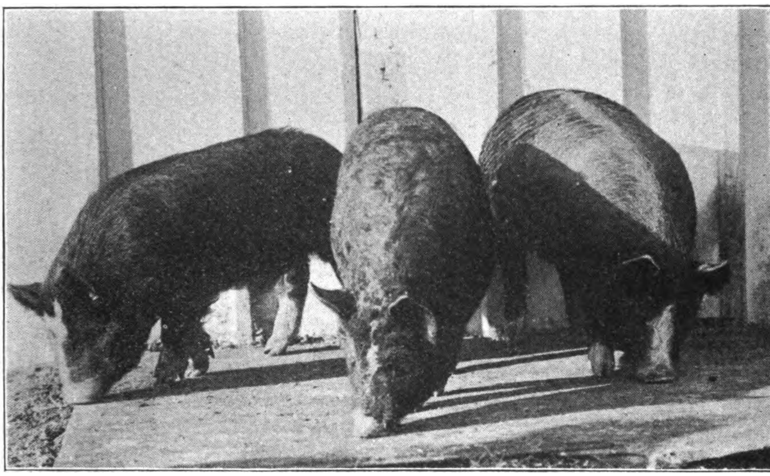


Figure 4. Lot II which received inorganic phosphorus in large amounts showing the thrifty appearance of animals fed in this manner at end of experiment.

bones, while all other lots contained from 46 to 55 per cent of ash in these bones.

LOTS 2 AND 3.—The animals in these lots, with one exception, showed progressive growth throughout the history of the experiment. Number 403 alone failed to make as vigorous development as all the other animals. This, we believe, is to be attributed at least in part to a constitutional weakness. The somewhat unpalatable ration demanded animals of initially strong and vigorous constitutions and we feel fortunate that in this experiment our selections were generally successful. The intake of phosphorus in Lot 2 was 6.57 grams per pig daily, when the feed consumption was 2.2 pounds. While in Lot 3 it was 3.84 grams per pig for a like consumption of feed. In the first instance 29 per cent of the intake was in organic form,

2

while but 17 per cent was in a similar form in the ration fed Lot 3.

The animals' appetites remained keen throughout the experiment. There was no manifestation of weakness of any of the animals at any time. On March 20 one animal from the lot receiving the smaller quantity of inorganic phosphate was killed.

The examination of the tissues for dry matter as well as for their calcium and phosphorus content are shown in Tables IV and V, and indicate practically similar quantities as in the tissues of animals receiving normal feeds.

The bones showed an appreciable increase in size over those of the animals from Lot 1 and were somewhat larger than those receiving the unsupplemented feeds. Their texture was compact and in appearance silky and hard. The specific gravity was 1.157 and the breaking strength three fold that of the basal lot and per square millimeter equal to that of the standard fed lot. The weight of the skeleton surpassed that of all slaughtered animals from the other lots. The ash content of the thigh bones was 55 per cent as compared with but 31 per cent in the basal lot.

The two animals remaining in this lot, both females, were continued on the ration with the lower content of supplemented calcium phosphate. Both animals were bred. They developed into strong, vigorous sows. At the time of farrowing number 406 weighed 280 pounds, while number 416 weighed 310 pounds. Six pigs were born in each litter. The mothers appeared to furnish a fair milk supply as indicated by the normal growth of the young. The young were allowed to follow the mothers, feeding from their rations as they desired. When they had reached an individual weight, approximating 30 pounds, they were separated from the mother and three of the young animals continued on the inorganic phosphorus ration in the experiment of 1907–8. They continued to make fair gains attaining weights of about 75 pounds at four months of age. At that age one animal showed a breaking strength of its thigh bones of 1.9 pounds per square millimeter, a result not differing greatly from that of a normally fed animal.

LOTS 4 AND 5.—These animals received the non-supplemented normal feeds and were maintained as standards for comparison throughout the experiment. Lot 4 received its supply of phos-

phorus largely in the form of phytin. Probably 85 per cent of the ingested phosphorus was in this form. The remainder consisted of nucleins and lecithins. There was nothing in the

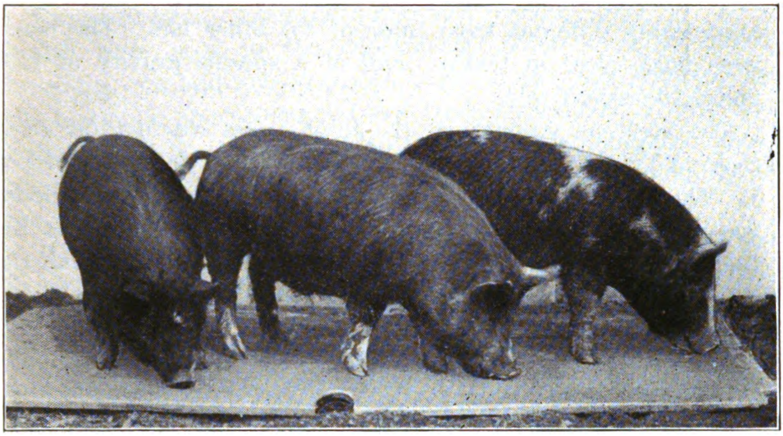


Figure 5. Lot IV receiving phytin, phosphorus of whole wheat bran ration showing thrifty appearance of animals at end of experiment.

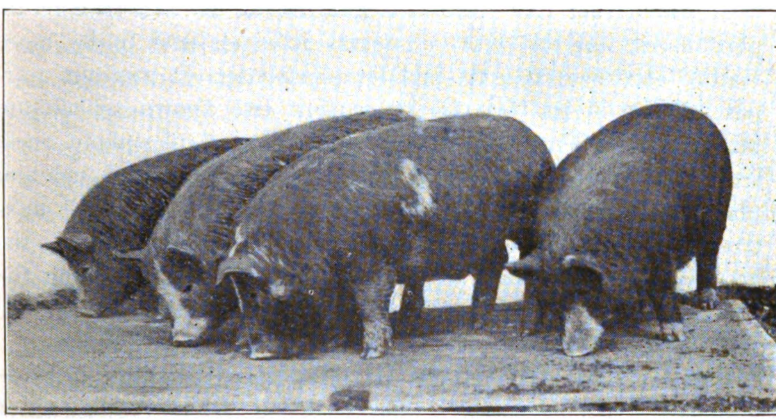


Figure 6. Lot V receiving a variety of forms of organic phosphorus. Animals generally thrifty at end of experiment.

history of this lot to indicate that these animals were not properly nourished. Consistent increases in weight were made by all of them.

Lot 5 received its phosphorus in the form of nucleins, lecithins, and phytates. There was not a preponderance of any

one form. These animals gained in weight regularly and in every way were vigorous and strong.

The dry matter, calcium and phosphorus content of the tissues of slaughtered animals from both Lots 4 and 5 were not appreciably different from those of the other lots. The bones were hard, close in texture, and of a specific gravity of 1.10 and 1.19 respectively.

The breaking strength of the thigh bones was not far from those of Lots 3 and 4 and approximately three times that of Lot 1. The ash content of the corresponding bones of the skeleton was respectively 53 per cent for Lot 4, and 46 per cent for Lot 5. This, it will be remembered, was much higher than the ash content of Lot 1 and comparable with that of Lot 3.

EXPERIMENT II.

In the winter of 1907–8, the work described in the foregoing pages was repeated and somewhat extended. Our previous plan included the use of but one form of inorganic phosphorus, namely, the precipitated calcium phosphate. It has been stated that this form is a mixture of di- and tri-calcium phosphates, and by some observers it is claimed to be more readily absorbed than tri-calcium phosphate. It was our purpose to use in the present experiment two known tri-calcium phosphates, a bone ash and a crude ground phosphate rock, known as floats. The experiment with precipitated calcium phosphate was again repeated, as also were the standard mixtrue grain experiment, the whole bran experiment, and the basal or low phosphorus experiment. So striking had been the results of the previous year, that it was considered necessary to repeat the work.

THE RATIONS.—These were in all respects similar to those used in Experiment I. A basal ration which consisted of washed bran, wheat gluten and rice, fortified with the sugar-salt mixture, was again used. To this basal ration was added, in known quantities, the forms of inorganic phosphorus to be tested. An approximately equivalent intake of phosphorus was secured in each case. In addition to these, a ration rich in phytin was fed, secured by the use of whole wheat bran. A standard ration made up of oats, corn, middlings and oil meal, which would furnish a variety of forms of phosphorus, formed

the sixth ration. In all there were six different rations and six lots of animals were used. As in the previous experiment, the protein supply in the first five rations was regulated by the use of wheat gluten.

EXPERIMENTAL ANIMALS.—Eighteen young pigs in good health were used in the experiment. They were of mixed breeding. In addition to the 18, three of the pigs farrowed by the inorganic phosphorus fed sow from Experiment I were distributed in the various lots to again receive inorganic phosphorus. The average weight of the 18 pigs at the beginning of the experiment was 49 pounds.

MANAGEMENT OF THE EXPERIMENT.—The management of the experiment was similar in all details to that of the former experiment, except that small outside enclosures were provided for each lot, in addition to the sleeping pens. The animals had free run to these pens during the day. At night they were confined to the barn. The dry enclosures were free at all times from vegetation. Feeds were mixed weekly and animals fed twice daily. They were weighed once a week at a definite time.

COLLECTION OF EXCRETA.—Toward the end of the experiment an animal from each lot, except the standard lot, was placed in an especially constructed cage and the urine and feces separately collected. This was to afford data on the channels of phosphorus elimination and quantities absorbed and retained. A description of the apparatus in use in our nutrition studies for the collection and separation of the excreta of animals of the size of a 50 to 100 pound pig or sheep will be found in a separate publication by Professor E. V. McCollum.

SEQUENCE OF FEEDING.—Feeding began October 15. A preliminary period of two weeks was used in accustoming the animals to the ration before actual records were kept. These were begun October 29.

The mixture of feeding materials consisted of 28½ pounds of ground rice, 6 pounds of wheat gluten, and 15 pounds of bran (either washed or whole), to which was added in the case of the washed bran ration, 500 grams of the sugar-salt mixture. This again gave us the basal ration.

The ration carrying precipitated phosphate was made by adding 625 grams of precipitated phosphate to the above proportion of feeds. In the case of bone ash, 625 grams were added

and in the case of floats, 875 grams of the ground crude phosphate rock. This supplied approximately equal quantities of phosphorus in each ration. The initial consumption of feed was again similar to that in Experiment I, and was increased as the animal demanded it. The pigs receiving the basal ration did not increase the daily initial consmuption of about 2 1/5 pounds daily per animal. All others receiving supplemental rations approached at the end of the experiment a daily consumption of three pounds per pig. The whole bran and standard ration consumption somewhat exceeded this. The experiment covered 123 days.

The tables that follow are summarized in exactly the same way as was done in Experiment I. In addition are tables showing the balance of phosphorus and the amounts retained by the animals receiving this element in the different forms.

Table VIII. Composition of feeding materials used.

Table IX. Initial ration of each lot, including daily intake of total phosphorus.

Table X. Total average gains in weight of each lot.

Table XI. Percentage of solids in the lean muscle of the slaughtered animals from the first five lots.

Table XII. Dry weight of skeleton and breaking strength of thigh bone of the slaughtered animals.

Table XIII. Ash content of corresponding bones from each animal.

Table XIV. Phosphorus balance sheet of pigs from the several lots.

TABLE VIII.—COMPOSITION OF FEEDING MATERIALS USED.

FEED.	Water.	Protein.	Fat.	Phosphorus.
	Per cent.	Per cent.	Per cent.	Per cent.
Rice	13.60	8.20	0.38	0.105
Wheat Gluten	7.	73.	1.50	.205
Washed Bran	7.60	12.20	4.10	.110
Whole Bran	10.80	14.50	4.60	1.47
Corn [1]	10.60	10.30	5.	.313
Oats [1]	11.	11.80	5.	.355
Middlings [1]	12.1	15.60	4.	.870
Oil Meal [1]	10.1	33.20	3.	.789
Calcium Phosphate				15.75
Bone Ash				16.38
Floats				11.66

[1] Henry: "Feeds and Feeding." Average Composition of American Feeding Stuffs.

TABLE IX.—INITIAL RATION OF EACH LOT, INCLUDING DAILY INTAKE OF TOTAL PHOSPHORUS.

	Feeds.	Amount per pig daily.	Total phosphorus.
		Pound.	Grams.
Lot 1	Ground Rice	1.24	0.56
	Washed Bran	.65	.32
	Wheat Gluten	.26	.24
	Sugar-Salt Mixture	.048	.00
	Total	**2.198**	**1.12**
Lot 2	Ground Rice	1.20	0.54
	Washed Bran	.63	.30
	Wheat Gluten	.25	.23
	Sugar-Salt Mixture	.046	.00
	Precipitated Phosphate	.059	4.22
	Total	**2.185**	**5.29**
Lot 3	Ground Rice	1.20	0.54
	Washed Bran	.63	.30
	Wheat Gluten	.25	.23
	Sugar-Salt Mixture	.046	.00
	Bone Ash	.059	4.38
	Total	**2.185**	**5.45**
Lot 4	Ground Rice	1.20	0.54
	Washed Bran	.63	.30
	Wheat Gluten	.25	.23
	Sugar-Salt Mixture	.046	.00
	Floats	.078	4.13
	Total	**2.204**	**5.20**
Lot 5	Ground Rice	1.26	0.57
	Washed Bran	.67	4.47
	Wheat Gluten	.27	.24
	Total	**2.20**	**5.28**
Lot 6	Ground Corn	0.67	0.95
	Ground Oats	.67	1.07
	Wheat Middlings	.67	2.64
	Oil Meal	.22	.79
	Total	**2.23**	**5.45**

TABLE X.—GAINS IN WEIGHT, POUNDS.

LOT 1.—BASAL.

	Animal.		
	No. 516.	No. 517.	No. 518.
Initial Weight, Oct. 29	52	54	39
Nov. 29	54	68	40
Dec. 29	68	92	45
Jan. 29	68	108	49
Feb. 29	75	120	58
Mar. 20	74	109	57
Gain	22	55	18
Average gain of lot		32	

LOT 2.—PRECIPITATED PHOSPHATE.

	Animal.			
	No. 510	No. 511.	No. 512.	Pig from old experiment.
Initial weight, Oct. 29	50	49	50	39
Nov. 29	58	58	61	48
Dec. 29	80	75	65	67
Jan. 29	87	93	64	72
Feb. 29	102	108	64	78
Gain	52	59	14	....
Average gain of lot		42		

LOT 3.—BONE ASH.

	Animal.			Pig from old experiment.
	No. 513.	No. 514.	No. 515.	
Initial weight, Oct. 29	67	45	38	28
Nov. 29	80	46	39	31
Dec. 29	110	54	45	38
Jan. 29	133	556	449	42
Feb. 29	145	57	53	....
Gain	78	12	15	....
Average gain of lot		35		

LOT 4.—FLOATS.

	Animal.			Pig from old experiment.
	No. 507.	No. 508.	No. 509.	
Initial weight, Oct. 29	60	42	46	37
Nov. 29	70	47	47	45
Dec. 29	90	62	57	56
Jan. 29	104	66	69	66
Feb. 29	125	71	80	....
Gain	65	29	34	....
Average gain of lot		43		

LOT 5.—WHOLE BRAN.

	Animal.		
	No. 504.	No. 505.	No. 506.
Initial weight, Oct. 29	53	51	43
Nov. 29	72	68	45
Dec. 29	91	82	59
Jan. 29	103	100	66
Feb. 29	125	115	80
Gain	72	64	37
Average gain of lot		58	

LOT 6.—STANDARD.

	Animal.		
	No. 501.	No. 502.	No. 503.
Initial weight, Oct. 29	58	43	48
Nov. 29	75	52	58
Dec. 29	94	65	78
Jan. 29	106	87	95
Feb. 29	125	107	114
Gain	67	64	66
Average gain of lot		66	

TABLE XI.—PER CENT OF SOLIDS IN PARTS OF ANIMALS DRIED AT 100 DEGREES C. FOR FIVE HOURS. 1908.

PART.	LOT.				
	1. Basal.	2. Precipitated phos.	3. Bone ash.	4. Floats.	5. Whole bran.
Number of animal	516	512	514	506	509
Leg muscle	24.5	24.4	25.3	23.2	27.1
Tenderloin muscle	22.7	25.0	21.8	25.3	22.5

TABLE XII.—DRY WEIGHT OF SKELETON AND BREAKING STRENGTH OF THIGH BONES.

PART.	LOT.				
	1. Basal.	2. Precipitated phos.	3. Bone ash.	4. Floats.	5. Whole bran.
Number of animal	516	512	514	506	509
Weight of skeleton	870 gm.	950	950	1,495	850
Weight of animal at slaughter	77 lbs.	87	58	82	87
Breaking strength of thigh bone, pounds per square millimeter	0.87	1.70	1.77	1.65	1.86
Diam. millimeter	16	16	15.5	20	17

TABLE XIII.—ASH CONTENT OF CORRESPONDING BONES FROM EACH ANIMAL.

PART.	LOT.				
	1. Basal.	2. Precipitated phos.	3. Bone ash.	4. Floats.	5. Whole bran.
Number of animal	516	512	514	506	509
Specific gravity bone	0.984	1.15	1.12	1.19	1.14
Ash (thigh bone) per cent	33	46	53	57	54

TABLE XIV.—PHOSPHORUS BALANCE SHEET.

	Date.	Total phosphorus ingested.	Total phosphorus urine.	Total phosphorus feces.	Total phosphorus (inorganic) feces.	Total phosphorus retained.
		Grams.	Grams.	Grams.	Grams.	Grams.
LOT 1. Basal............	Feb. 4....	0.779	0.0104	0.705	0.145	0.064
	" 5....	.806	.0157	.465	.069	.326
	" 6....	.54	.021	.271	.117	.248
	" 7....	.837	.021	.363	.216	.453
	" 8....	1.258	.0182	.375	.093	.865
	" 9....	1.27	.0179	.593	.238	.66
	" 10....	1.27	.0167	.797	.215	.457
	" 11....	1.208	.017	.469	.189	.722
	" 12....	1.121	.0257	.611	.192	.485
	" 13....	1.281	.0204	.505	.186	.756
	" 14....	1.281	.0367	.595	.201	.65
	" 15....	1.283	.0274	.548	.156	.708
	Total.....	12.934	.2481	6.297	....	6.394
	Average...	**1.08**	**.02**	**.52**	....	**.53**
LOT 2. Precipitated phosphate	March 21	4.61	0.257	2.52	....	1.84
	" 22	5.17	.461	2.26	....	2.45
	" 23	5.76	.214	2.48	....	3.07
	" 24	4.67	.585	2.39	....	1.8
	" 25	4.9	.377	2.59	....	1.94
	Average...	**5.02**	**.378**	**2.45**	....	**2.22**
LOT 3. Bone ash........	March 28	3.27	0.206	1.99	....	1.08
	" 29	3.51	.27	2.3	....	.94
	" 30	4.16	.185	1.81	....	2.17
	" 31	4.87	.256	2.76	....	1.86
	April 1	4.39	.5	2.5	....	1.39
	" 2	4.28	.273	2.23	....	1.78
	Average...	**4.08**	**.281**	**2.26**	....	**1.54**
LOT 4. Floats...........	March 3	4.73	0.471	1.4	....	2.86
	" 4	3.28	.38	1.5	....	1.4
	" 5	4.39	.295	1.59	....	2.5
	" 6	4.98	.187	1.69	....	3.11
	" 7	3.7	.098	1.57	....	2.03
	" 8	4.8	.187	1.86	....	2.76
	" 9	3.95	.158	1.96	....	1.83
	Average..	**4.26**	**.253**	**1.65**	....	**2.35**
					Per cent.	
LOT 5. Whole Bran....	March 13	4.98	0.538	2.36	2.29— 97	2.09
	" 14	5.75	.5	2.5	....	2.75
	" 15	5.75	.483	1.39	1.34— 97	3.88
	" 16	5.75	.628	2.88	2.31— 80	2.24
	" 17	5.75	.705	2.78	2.45— 88	2.27
	" 18	5.75	.66	2.83	2.58— 91	2.26
	" 19	5.75	.73	3.07	3.07—100	1.95
	" 20	5.75	.688	3.62	3.25— 90	1.45
	Average..	**5.65**	**.666**	**2.66**	....	**2.36**

DISCUSSION OF THE DATA FROM EXPERIMENT II.

The history of this experiment is a repetition of Experiment I and will be but briefly discussed.

LOT 1, BASAL.—This lot again repeated the phenomena observed in 1906–1907. With the low intake of phosphorus, 1.12 grams daily per pig, they failed to develop into strong vigorous pigs. An increase of body weight occurred in all cases and was considerable in No. 517. The attacks of weakness of limbs, stupor and a condition analogous to coma, were somewhat delayed, owing possibly to the opportunity for exercise in the outdoor pen, but nevertheless were strongly manifested after a lapse of three months. At first the attacks were mild, with partial recovery, but grew in violence until it was with difficulty that the animals were induced to take nourishment. The twitching tendency of the muscles, dragging the hind quarters and the peculiar attitude assumed when standing were shown by all the animals on this ration. After four months from the initial date loss of weight commenced and the experiment was discontinued. One animal from this lot was killed, and the others again restored to an apparently normal condition by the use of milk and middlings. The proportion of dry matter in the muscles examined was comparable with that of the animals receiving normal feeds.

The texture of the bones showed a decided variation from the bones of the animals of all other lots. They were spongy and loose in construction. Their breaking strength per square millimeter was but half that of the corresponding bones in the animals receiving either low phosphorus rations, supplemented with various forms of calcium phosphate, or normal feeds naturally supplying an abundance of this element. The specific gravity of the bones was less than one, while in all other lots it was greater than unity. The thigh bones showed but 33 per cent of ash, while the corresponding bones from all other lots contained from 46 to 57 per cent.

LOTS 2, 3 AND 4.—The rations of these lots differed from that of Lot 1 only in the single constituent, that of an added quantity of some form of calcium phosphate. Certain individuals unfortunately did not do well on the rations. This was confined to no single lot. The somewhat unpalatable ration pro-

duced by such material as our prepared washed bran, required animals of initial inherent strength and vigor. At no time, however, did any of the animals show symptoms of retrogression similar to Lot 1. No condition of body weakness, stupor, or coma, manifested itself. An examination of the table will show that certain individuals made as large gains in weight as those on standard feeds, and in every respect were as vigorous and strong.

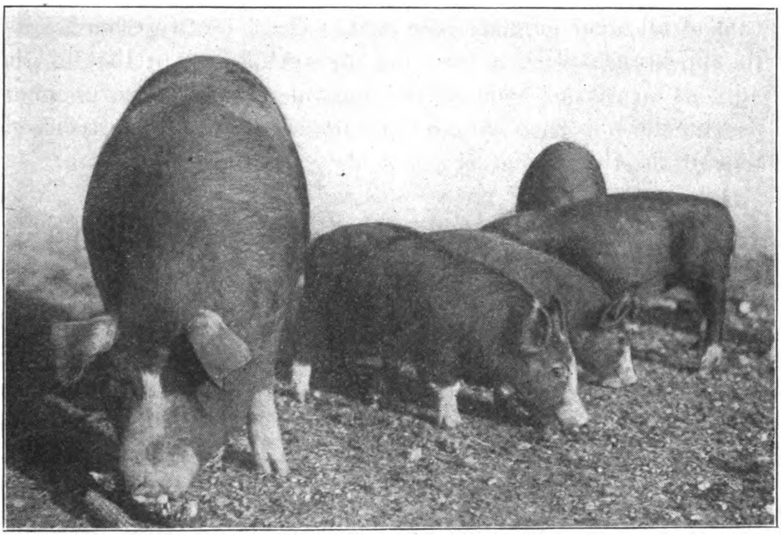


Figure 7. Sow and pigs fed inorganic phosphorus throughout experiment showing thrifty appearance of both mother and young.

On March 20 one animal from each lot was slaughtered. The proportion of dry matter in the two muscles examined was practically identical with that of the animal receiving normal feeds. The thigh bones from the pigs of all these lots were practically identical in breaking strength, while the ash content was from 46 to 57 per cent, as compared with but 33 per cent in the basal lot.

The animals carried over from Experiment I and continued on the low phosphorus rations, fortified with inorganic phosphates, made considerable development, doing quite as well as animals just starting on these rations. Whatever lack of thrift existed we believe to be attributed more to the difficult and naturally somewhat unsuited ration, rather than to the form of phosphorus administered.

LOTS 5 AND 6.—These animals received normal feeds and were maintained as standards for comparison throughout the experiment. In Lot 5 the ingested form of phosphorus was very largely in the form of phytin, while in Lot 6 the ingested phosphorus was more largely in the form of nucleins, lecithins and phytin, with a predominance of no single form. The animals gained in weight regularly and in every way were vigorous and strong. March 20 one animal from Lot 5 was slaughtered. The dry matter in the muscles was comparable with that of all other animals examined. The bones were hard, silky in appearance, with a breaking strength equal to that of the animals on rations receiving an equivalent of phosphorus in inorganic form. Their specific gravity was 1.14 and the ash content of the thigh bone 54 per cent.

DISCUSSION OF DATA ON INTAKE AND OUTGO OF PHOSPHORUS.

Toward the end of the experimental period a single animal from all lots except the standard ration was placed in a cage and an accurate balance of income and outgo of phosphorus determined. The first few days of collection were discarded. Only after the animal had become well accustomed to its surroundings were records commenced. Variation of intake of phosphorus was due, of course, to the variable amounts of food consumed daily.

PIG RECEIVING THE BASAL RATION.—While the intake of phosphorus averaged 1.08 grams daily the average amount retained was but one-half, or 0.53 grams daily. This manifestly was insufficient for complete nutrition. The presence of inorganic phosphorus in the feces indicates that the total absorption of ingested phosphorus has been greater than the figures for retention show. This animal was at a low ebb of vitality and certainly suffering from phosphorus starvation. It is a significant fact that even under such conditions there was an appreciable output of phosphorus representing, in all probability, phosphorus waste. The low content of ash in the skeleton strongly supports the view that the bones were serving as a reserve of calcium phosphate, from which the animal was drawing in order to supply the deficiency in the ingested feeds. This would easily account for the long delayed retrogression of the animal,

and for the fact that it maintained the phosphorus and calcium content of its tissues equal to that of a pig receiving an abundance of these elements.

PIG RECEIVING THE BASAL RATION, SUPPLEMENTED WITH INORGANIC PHOSPHATES.—The average intake of total phosphorus in the three lots varied from 4 to 5 grams daily. At least 80 per cent of the phosphorus was in inorganic form. The average amounts retained daily ranged from 1.5 grams in the bone ash fed pig, to 2.35 grams in the float fed pig. It is perfectly clear, of course, that the rate of growth, will, in a large measure, control the demand for phosphorous and calcium, causing thereby a variation in the amounts retained, dependent upon this factor. The proportion of calcium to phosphorus in the food supply is an additional factor in regulating the amount of phosphorus retained by the growing young, as was pointed out by Ingle. Just how far a plentiful supply of bases other than calcium can function in the retention of phosphorus for skeleton formation has not been determined. But an examination of the data reveals the fact that where the preponderating supply of phosphorus has been as a calcium phosphate there the percentage ash content of the bones was not appreciably larger than in cases where a very low supply of calcium to phosphorus for formation of a calcium phosphate existed. However, it is evident that in most cases the animals receiving calcium phosphates showed a tendency to the production of heavier skeletons. It is, of course, clear that for bone formation a proper porportion of calcium for ultimate formation of calcium phosphate must accompany the phosphorus intake. The fact that the proportion of phosphorus to calcium in tri-calcium phosphate is as 1:1.9, while in wheat bran it is as 1:0.09, at least suggests the thought that an added lime supply in the form of calcium carbonate could induce an increased proportional retention of the phosphorus of wheat bran for bone formation.

There were days when the data show as high a retention of 3.11 grams in the float fed pig. These variations in daily retention would depend largely upon the quantity of excreta voided and on the rate of growth. The data indicate that an intake of three grams of phosphorus daily for a growing 50-pound pig is the safe minimum quantity allowable. An additional supply of one to two grams daily for purposes of gut regulation through the action of the salts of phosphoric acid,

for the replacement of waste, and for as yet undetermined functions, appears much safer. The more insoluble floats did not fail to supply the required phosphorus, but appears in every way to have been as efficient as precipitated phosphates for these animals. Some 85 to 88 per cent of the excreted phosphorus passed through the gut. The form of this excreted phosphorus was almost entirely inorganic.

The extended investigation on the composition of farm animals at the Rothamsted Experiment Station affords data of a general character worth our consideration at this point. It was found at that station that the amount of ash in the entire animal (store pig) was 2.67 per cent, about 17.2 per cent of which was phosphorus. In a 50-pound pig this would approximate 105 grams. When the animal has increased to 150 pounds weight, allowing that at that weight the proportion of ash in the soft tissues was not decreasing, the phosphorus content would then be 315 grams. If this increase had been made in 100 days then the daily retention would have been about 2.1 grams of phosphorus. A more rapid increase in the growth would have increased this amount. With allowance for waste, indicated by the behavior of our animals under phosphorus starvation, the total daily requirements would not be far from the figures we have given.

PIG RECEIVING WHOLE BRAN RATION.—In this ration the form of phosphorus consisted of about 80 per cent phytin phosphorus, with the remaining 20 per cent in the form of nucleins and lecithins. No inorganic phosphates were contained in the intake. The average retention was 2.36 grams daily or about 42 per cent of the intake. The phosphorus excreted in the feces was almost wholly inorganic in form. It is very probable that the excreted phosphorus represented phosphorus that had already been absorbed. The fact that the blood contains a phytin splitting enzyme[29] while the ordinary intestinal enzymes are incapable of producing this cleavage strongly supports this view. From this point of view it is manifestly impossible to measure absorbed or "available" phosphorus compounds by simply estimating the phosphorus content of the feces and subtracting this amount from the total ingested phosphorus.

---

[29] Jour. of Biol. Chem., Vol. IV, No. 6, E. V. McCollum and E. B. Hart.

ASH IN THE BONES OF A PIG OF 40 POUNDS WEIGHT.—To make sure that the decreased ash content in the skeletal tissues in those animals receiving the low phosphorus ration was incident to lack of supply in the feeds and not the normal amounts in the bones when the pigs were placed in the experiment, a normally fed animal of 40-pound weight was slaughtered. The skeleton was cleaned of all meat by boiling in water and then dried at 60 degrees C. The air dried thigh bones showed 54.3 per cent of ash, confirming our conclusions, that the skeletal tissues were furnishing the calcium phosphate supply on the ration of low phosphorus intake.

DEDUCTIONS FROM THE TWO EXPERIMENTS.

The data secured from the two experiments support the following briefly summarized deductions.

1. INFLUENCE OF SUPPLY OF PHOSPHORUS.—A low phosphorus ration carrying 1.12 grams of phosphorus daily could not sustain growing swine. They became weak, with loss of the use of their limbs and completely collapsed after a period of three to four months. The supply of phosphorus for the nutrition of parts other than the skeleton was drawn from the skeleton during this low phosphorus intake. The skeleton lost its phosphorus, in company with calcium, probably as a calcium phosphate. The soft parts of the animal maintained the proportions of calcium and phosphorus very similar to the corresponding tissues of animals receiving an abundance of these elements.

An abundant supply of phosphorus in organic or inorganic forms had no influence on the proportion of phosphorus contained in the soft parts of the body. When the animal body is flooded with large quantities of calcium phosphate, the skeleton tissues not only become normally impregnated with the salts, developing strong bones, but up to a limiting capacity inherent in the animal, can still further add to the weight, size and density of these tissues. This is evidenced by the fact that when the calcium and phosphorus intake of pigs receiving a normal standard ration was increased by 25 grams daily of either precipitated phosphate, bone ash, or floats, for a period

of three months, the breaking strength of the thigh bones became per square millimeter 2.16, 1.84, and 2.19 pounds respectively, while those not receiving this addition remained at 1.77 pounds. These results were secured from animals of the same breed, age and as near alike in every respect as it was possible to select them.

These results, so far as the soft tissues are concerned are in entire harmony with the conclusions of Le Clerc and Cook,[30] who have shown that with dogs and rabbits there is not an increased retention of phosphorus by the soft tissues when the salts of this element are added to a food containing normal amounts of phosphorus. However, over long periods of feeding with additional supplies of calcium phosphate the ash content of the skeletal tissues of pigs is increased.

2. INFLUENCE OF FORM OF PHOSPHORUS WHEN THE ORGANIC SUPPLY, AS NUCLEINS AND LECITHINS, IS LOW.—There appears to be no superiority, as source of supply of any one form among the forms of phosphorus tested, when supplementing rations extremely low in this element. This holds only for swine. It may not be true in other classes of animals. The forms tested were precipitated calcium phosphate, bone ash, floats, and the organic form, phytin. All were able to furnish the necessary supply for vigorous healthy development when the intake of nuclear and lecithin phosphorus was low.

3. RETENTION OF VARIOUS FORMS OF PHOSPHORUS AND MINIMUM SUPPLY NECESSARY.—The amount of phosphorus retained by growing pigs was not so much influenced by the form of phosphorus administered, as by the vigor and rate of development of the animal. The average amounts retained daily when the supply was entirely organic was 2.36 grams and when 80 per cent of the supply was in the form of floats, it was 2.35 grams daily. It is apparent from this data that a safe minimum requirement of at least three grams daily is necessary for a vigorous growing pig of 50 pounds weight. It is also manifest that even in phosphorus starvation there is an appreciable daily excretion of this element. This indicates a continuous catabolism of phosphorus holding-bodies in the animal tissues. and that such portions as have been catabolized escape further use and are eliminated. It is probably safe for the reason

[30] Jour. Biol. Chem. Vol. II, No. 3, 1906.

stated above to estimate the daily requirement for a growing 50-pound pig at from four to five grams of phosphorus.

4. CATABOLISM OF PHYTIN.—When the food supply of phosphorus was entirely organic and 80 per cent of it consisted of phytin, the form of the excreted phosphorus was almost wholly inorganic. Pepsin or trypsin do not possess the power to cleave this body into an inorganic form and the conclusion of Scofone[31] is in harmony with the view that none of the enzymes of the digestive tract are capable of inducing this change. The presence of a phytin splitting enzyme, phytase, in the blood and liver of mammals is strong evidence that this body is absorbed from the intestinal tract and afterwards undergoes cleavage, while the excess and unnecessary quantities are again largely eliminated through the gut in inorganic forms.

5. EVIDENCES OF SYNTHESIS OF ORGANIC FORMS OF PHOSPHORUS FROM INORGANIC FORMS.—The data does not furnish conclusions of a definite character on the question of the synthesis of organic phosphorus bodies from inorganic phosphates by the animal cell. At no time was the supply of organic phosphorus in the basal ration low enough to give data on this point. While the addition of inorganic phosphates supplied the necessary factor to the basal ration for successful growth, yet the intake of organic forms would supply at least one gram per day and one-half of this was retained. Facts are available which allow us to calculate intelligently on an assumed case. A pig of 50 pounds increased its weight to 100 pounds in two months on our basal ration, provided with inorganic phosphates. It has been found with steers[32] that exclusive of blood and the contents of the stomach and intestines, the soft tissues represent about 51 per cent of the total body weight. With swine the proportion is larger, probably not far from 60 to 65 per cent. Assuming that 60 per cent of the increased live weight is soft tissue and that 0.1 per cent is the average total organic phosphorus content in such tissues, then the total organic phosphorus necessary for the development of these tissues at the end of 60 days was but 13.6 grams; yet the supply of organic phosphorus from our basal ration over a period of two months had been at least 60 grams. This calculation does not take into consideration the

[31] Abstract in Biol. Chem. Central Blatt, III, p. 606, 1905.
[32] Jordan Me. Agri. Expt. Sta., Rpt. 1895, p. 36

amount of organic phosphorus daily catabolized by the animal. There exists no data on the amount of phosphorus broken down into inorganic forms by the metabolic processes in the nuclei, when the animal is receiving a ration free from phosphorus but otherwise satisfactory. That this amount is not inconsiderable is strongly suggested by the data in Table XIV, Experiment II. The pig receiving a supply of phosphorus too small to permit of a normal development of muscular and skeletal tissues was still excreting on an average 0.55 grams of phosphorus every day. While this figure cannot be taken to represent the amount daily catabolized by the animal, it does point toward the inability of the animal to reduce this phosphorus loss below a certain level. The work of Grindley[33] has shown that the average total phosphorus content of beef muscle is approximately 0.25 per cent and that 75 per cent of it is water soluble. If we allow that all the insoluble phosphorus exists in organic forms, which is probably very near the truth, and that the soluble inorganic phosphorus is 0.08 per cent, then the total organic phosphorus is approximately 0.14 per cent. Our own determinations on the lean meat of swine placed the total phosphorus content as considerably lower. From this it is clear that our allowance of 0.1 per cent of organic phosphorus in the soft tissues is, if anything, high.

The final solution of the problem of whether the function of the synthesis of organic phosphorus-bearing bodies from inorganic phosphorus and organic radicals is resident in the animal cell, or whether these bodies must be supplied as such in the feeding materials, is under way in this laboratory. It is clear that should further research prove that this synthetic function is a part of the animal's equipment, then the problem of form of supply for production, so far as the phosphorus bearing bodies are concerned, becomes a secondary matter and whatever enhancement of growth accrues from the use of special types of phosphorus-bearing bodies, this enhancement in production must result from the physiological effect of the non-phosphorus-bearing complexes to which the phosphorus is attached.

---

[33] Jour. Am. Chem. Soc., Vol. XXVIII, p. 25, 1906.

SUMMARY.

1. On the ration extremely low in phosphorus, pigs made as large gains up to 75 or 100 pounds when starting at weights of from 40 to 50 pounds as animals receiving an abundance of this element. After reaching this point loss of weight began, followed by collapse.

2. When such low phosphorus rations as induced the above symptoms were supplemented with calcium phosphates no untoward results appeared. Animals fed a low phosphorus ration, supplemented with inorganic phosphates, made as vigorous a development as others receiving their phosphorus supply wholly in organic form.

3. Precipitated calcium phosphates—a mixture of di- and tri-calcium phosphates—gave no better results than did floats, a crude tri-calcium phosphate.

4. Phytin as the supply of phosphorus gave no better results than the inorganic phosphates.

5. A young animal of 40 pounds weight receiving inorganic phosphates, together with other salts as supplementary to a ration very low in mineral constituents, grew to be an animal of 280 pound weight, bore a litter of fairly vigorous pigs, which on the same ration completed the cycle back to 80 pounds, while animals on the same ration, less the inorganic phosphates, collapsed in three months with loss of weight accompanied by a loss of the use of their limbs.

6. Determinations of calcium and phosphorus in the principal organs and tissues of the animals on the low phosphorus ration, showed that they maintained the proportion of these elements constant and comparable to that of normally fed pigs.

7. The percentage of ash in the skeleton of pigs on the depleted phosphorus ration was reduced to nearly one-half that of pigs receiving a normal ration, or a phosphorus poor ration supplemented by an inorganic phosphate.

8. The marked reduction in the quantity of ash of the bones of the animal receiving an insufficient supply of calcium phosphates, together with the ability of the animal to build up a skeleton very rich in calcium phosphate when an abundance of the latter is supplied in inorganic forms, strongly points to the possession of a synthetic power by the animal which en-

ables it to convert inorganic forms of phosphorus into the organic forms demanded by its body.

9. When the animals were starving for phosphorus they drew this element from the skeleton, but removed calcium and phosphorus in the proportions found in tri-calcium phosphate.

10. The daily phosphorus supply for a 50 pound growing pig should be at least three grams. A supply of four to five grams is probably a safer quantity.

11. The data furnishes no positive evidence of the synthesis of nucleo-proteids or other organic phosphorus-bearing complexes from inorganic phosphates in the animal body.

Factors Influencing the Phosphate Content of Soils.

I. Phosphate Content of Soils as Affected by Methods of Farming.

A. R. WHITSON AND C. W. STODDART.

The importance of a careful study of the loss of phosphates under cropping conditions cannot be overestimated. Unlike nitrogen this element cannot be collected from an inexhaustible supply, and unlike potash it is being constantly removed from the soil in ways which are impossible to prevent with the present conditions of farm practice. Phosphorus is used in the growth of the grain and is sold from the farm. That portion of grain which goes into human food is probably lost beyond recovery; and that portion which goes into cattle feed is very frequently lost because of carelessness in handling manure. It must also be remembered that the amount of phosphorus originally in soils is very small.

As yet no complete study of the phosphate content of Wisconsin soils has been made, but Table I gives the determinations of phosphoric anhydride so far made at this Station on samples of virgin soils by the ordinary fusion method. In estimating the number of pounds of phosphoric anhydride in an acre of soil, eight inches deep, it has been assumed that sands weigh 2,500,000 pounds per acre; loams, 2,000,000 pounds; mucks, 1,000,000 pounds; and peats 350,000 pounds.

TABLE I.—PHOSPHORIC ANHYDRIDE IN WISCONSIN VIRGIN SOILS, SURFACE EIGHT INCHES.

Type.	Lab. No. of sample.	Locality.	P_2O_5 Per cent.	P_2O_5 Pounds per acre.
Muck	22, 567, 1076, 1078, 1086, 1096, 1080	Madison	0.31	3,100
		Racine	.17	1,700
Peat	62	Marinette	.22	770
	106, 107, 108	Horicon	.40	1,400
	1105	Mather	.14	490
	1106	Phillips	.25	875
Sand	1107	Sparta	.04	1,000
	46	Black River Falls	.10	2,500
	441	Iron River	.10	2,500
	558	" "	.11	2,750
	48	Lac du Flambeau	.18	4,500
	146	Peet	.01	250
Heavy red clay	127	Superior	.15	3,000
	696	Ashland	.09	1,800
Southwest loams	247	Onalaska	.21	4,200
	278	South Wayne	.28	5,600
	240	Viroqua	.19	3,800
	253	Lancaster	.12	2,400
Southeast loams	532	Sussex	.18	3,600
	988	Milton Jct	.21	4,200
	741	Janesville	.09	1,800
	753	"	.17	3,400
	963	Edgerton	.22	4,400
	915	"	.22	4,400
	924	"	.18	3,600
	918	"	.13	2,600
	942	"	.28	5,600
	971	"	.08	1,600
	920	"	.13	2,600
	997	"	.20	4,000
	928	"	.14	2,800
	831	Evansville	.15	3,000
	833	"	.31	6,200
	848	"	.20	4,000
	887	"	.17	3,400
	860	"	.14	2,800
	866	"	.12	2,400
	543	Cambridge	.09	1,800
	735	Afton	.11	2,200
North-central loams	659	Crandon	.18	3,600
	649	Radisson	.15	3,000
	652	Ladysmith	.13	2,600
	657	Tony	.21	4,200
Average			**0.17**	**2,940**

From this table it may be noticed that the average phosphoric anhydride content of soils is 0.17 per cent, but there is a very large variation not only between different types of soils, but also between different samples of the same type. The soils chiefly deficient in phosphates are the peats and sands. The amount in peats expressed in per cent is large, but when calculated on the basis of 12 pounds of dry matter per cubic foot[1] it means that the surface eight inches contains only 490 to 1,400 pounds of phosphoric anhydride per acre. In the sands there is a very wide variation, running from 0.01 per cent to 0.18 per cent. On the whole the clays of the southern part of the state appear to have a fair supply of phosphate, although the average is not large.

In view of the experience of older states, that phosphorus very quickly becomes the limiting element in crop production, it is evidently a matter of the very greatest importance to determine the actual effect of different farm practices on the phosphate content of soils. This has been studied with reference, first, to the results on land which has been cropped almost continuously to small grains and corn, with little or no manure; and, second, on land which has been heavily cropped to tobacco with very large applications of manure. The determinations of phosphoric anhydride were made on pairs of samples, one from the cropped field, and the other from the adjacent virgin soil. The surface eight inches were taken in every case, and a field of at least 10 acres constituted each cropped sample. Every precaution was taken to select virgin soils which corresponded in topography, drainage, and physical character to the cropped soils.

EFFECT OF EXHAUSTIVE CROPPING.

Nine pairs of samples have been studied from fields which have been very largely exhausted by 40 to 60 years of cropping to grain or corn, with little or no manure. The following is a brief outline of their history:—

No. 1. (Laboratory Sample No. 240-239), Viroqua. Cropped 50 years, chiefly to wheat, corn, and oats. It has had only two dressings of manure, but the land is now in a good state of fertility and is producing good crops.

---

[1] From actual determinations on samples consisting of a cubic foot of peat taken at different points in the state.

No. 2. (247-246), Onalaska. Cropped about 40 years, chiefly to corn and oats. It has become badly exhausted and now shows acid reaction.

No. 3. (253-252), Lancaster. Cropped 50 years, largely to corn, oats, and timothy. No manure has been used. The fertility is now at a low stage.

No. 4. (278-277), South Wayne. Cropped 60 years, largely to wheat during the first 10 or 12 years; then corn and oats; clover 10 years. The land is now in a depleted condition.

No. 5. (532-531), Sussex. Cropped 58 years; 23 to wheat, 14 to barley, 12 to oats, and 9 to corn. It has been manured but once and is now in a badly depleted condition.

No. 6. (741-740), Janesville. Cropped 59 years, chiefly to wheat, timothy, rye, oats, and corn. No manure has been applied and the field is now producing small yields.

No. 7. (753-752), Janesville. Cropped 63 years. During the first 34 years wheat was grown almost continuously. Since 1878 it has been rotated to corn, barley, oats, and rye. It has never been seeded down or manured and is in a badly exhausted condition.

No. 8. (963-962), Edgerton. Cropped about 60 years, largely to wheat at first, but during the last 40 years it has been farmed in a rotation, consisting of two crops of corn, one of oats, and two of clover and timothy, of which the first was cut and the second pastured. The field has not produced good crops during the last 10 years. It has been manured but once.

No. 9. (988-987), Milton Junction. Cropped 52 years, chiefly to wheat during the first 15 years. Since then it has been rotated to oats and barley with a few years of timothy. It has been manured 10 times with an average of 10 loads per acre each time. The field does not now produce good crops.

In estimating the amount of phosphoric anhydride removed by crops it has been assumed that corn, small grains, and timothy have removed 20 pounds of phosphoric anhydride from every acre each year and clover has removed 25 pounds. It is recognized that there is a difference in the amount of phosphoric anhydride removed by each crop, but since at best only estimates of yields were obtainable, and at that merely the statement "average crops" had to suffice frequently, and, morever, since the yields in many cases deteriorated, it was thought advisable to use a fixed average amount. Twenty pounds per acre is such an amount for grains. It has been assumed that each load of manure applied contained seven pounds of phosphoric anhydride, estimating a load at one ton and the phosphoric anhydride in the manure at 0.35 per cent,[1] which is an average amount. Where an application of manure had been made, but no amount given, 10 loads per acre have been estimated as an average application. Soil No. 8 was pastured 10 years, and a very rough estimate places the amount of phosphoric anhydride at 70 pounds added in manure. In estimating the number of pounds of phosphoric anhydride per

[1] Snyder, H., "Soils and Fertilizers," 3rd Ed., p. 159.

acre in the soil, it has been assumed that the surface eight inches weighs 2,000,000 pounds.

Table II gives the results of the analyses of the virgin and cropped soil; the excess of phosphoric anhydride in virgin soils over cropped soils, expressed in pounds per acre; the estimated amount of phosphoric anhydride removed by crops, and added in manure; and the loss in excess of that removed by crops.

TABLE II.—INFLUENCE OF EXHAUSTIVE CROPPING ON PHOSPHATE CONTENT OF SOILS, SURFACE EIGHT INCHES.

No.	No. of Lab. sample.	Per cent P_2O_5 in virgin soil.	Per cent P_2O_5 in cropped soil.	POUNDS PER ACRE, ESTIMATED.				
				Excess of P_2O_5 in virgin over cropped soil.	Amount taken by crops.	Added in manure and fertilizer	Removed by crops more than added in manure and fertilizer.	Loss above crop.
1	240—239	0.19	0.19	....	1,000	140	860	—860
2	247—246	.21	.12	1,800	800	0	800	1,000
3	253—252	.12	.08	800	1,000	0	1,000	—200
4	278—277	.28	.14	2,800	1,250	0	1,250	1,550
5	532—531	.18	.13	1,000	1,160	70	1,090	10
6	741—740	.09	.06	600	1,180	0	1,180	—580
7	753—752	.17	.09	1,600	1,260	0	1,260	340
8	963—962	.22	.13	1,800	1,080	70	1,010	790
9	988—987	.21	.16	1,000	1,040	700	340	660
Average......		**0.185**	**0.120**	**1,255**	**1,086**	**109**	**977**	**301**

From this table it appears that on the average over one-third of the total phosphoric acid originally contained by the soil has been lost. In all except one case the analyses indicate a smaller percentage of phosphoric acid in the cropped than in the virgin soil, and in that case the per cent contained is the same. The last column of Table II, headed "Loss above crop," contains several negative figures. These mean that the crops have removed more phosphoric anhydride than the analytical results show. The discrepancies are due partly to variations in the soil not overcome by sampling, to variations between the field and the area where the virgin soils were taken, and to errors in estimating crop yields. When the amount estimated to have been removed by crops, minus that added by manure, is compared with that indicated to have been lost by the analysis, it is seen that on the average the two are almost the same, only 301 pounds per acre having been lost otherwise than through crops. This means a loss of but 8 per cent above crops.

While the number of samples so far studied is too small to be made the basis of final conclusion on this matter, it is evident that the loss of phosphoric anhydride under conditions of constant cropping and no return, is largely caused by the removal of the crops, and this may amount to 30 per cent of the total quantity contained in the soil originally.

EFFECT OF HEAVY MANURING.

The custom of using large amounts of manure on tobacco lands raises the question as to whether or not the soil retains the essential elements so applied in excess of that taken by the crop. This problem is one which cannot be settled by a few isolated experimental plots which have been under control for a long period of years, since the retention of these elements by the soil will undoubtedly vary with the differing character of the soil. It seemed, therefore, highly desirable to study this matter on a considerable number of fields where the practice of heavy manuring has been followed for a long period of years, although it was possible to get only estimates either of the crop yields or of the amount of manure applied. The tobacco sections of Wisconsin afforded exceptional opportunities for this study, and determinations have been made on 16 fields, chiefly in Dane and Rock counties. The following is a brief history of these fields:

No. 1. (543-542), Cambridge. Cropped 30 years to tobacco. Fifteen loads of manure per year have been applied.

No. 2. (735-734), Afton. Cropped 40 years. The number of crops and estimated yields are as follows: Tobacco 30 years, 1,500 pounds per acre; sugar beets, 2 years, 18 tons; corn, oats, and some wheat, average yields. It has been manured 30 times, 25 loads per acre, except last year when about 60 loads per acre were applied.

No. 3. (831-830), Evansville. Cropped 60 years. The number of crops and estimated yields are as follows: Wheat, 25 years, 25 bushels per acre; timothy and clover, 5 years, 2 tons; tobacco, 30 years, 1,350 pounds. It has been manured 30 times, 10 loads per acre. Was seeded once to rye and used as hog pasture.

No. 4. (833-832), Evansville. Cropped 32 years. The number of crops and estimated yields are as follows: Tobacco 20 years, 1,500 pounds per acre; corn, 9 years, 50 bushels; rye, 1 year, good crop; wheat, 1 year, good crop; clover, 1 year, 3 loads. It has been manured 13 times, 10 manure spreader loads to the acre.

No. 5. (848-847), Evansville. Cropped 37 years. The number of crops and estimated yields are as follows: Tobacco, 30 years, 1,500 pounds; corn, 3 years; barley, 1 year; clover, 2 years; potatoes, 1 year, average crops. It has been manured 27 times, 30 loads per acre.

No. 6. (860-859), Evansville. Cropped 53 years. The number of crops and

estimated yields are as follows: Several years to wheat and small grains; tobacco, 32 years; wheat, 1 year; rye, 1 year; corn, 1 year, average yields. It has been manured 32 times, 23 loads per acre. Tobacco yields becoming poor. Other crops average.

No. 7. (866-865), Evansville. Cropped 57 years. The number of crops and estimated yields are as follows: Wheat until 1865; rotated to corn and oats, 10 years; timothy, 3 years; tobacco, 26 years, 1,600 pounds per acre; corn, 1 year; other crops, 1 year, average yields. It has been manured 26 times, 15 loads to the acre.

No. 8. (887-886), Evansville. Cropped 62 years. The number of crops and estimated yields are as follows: Corn, oats, and wheat, 25 years, with two years of wheat to one of corn; tobacco, 30 years, 1,500 pounds per acre. Used as hog pasture for three years. It has been manured 30 times, 20 loads to the acre.

No. 9. (915-914), Edgerton. Cropped 63 years. The number of crops and estimated yields are as follows: Wheat, and other small grains, 13 years; corn and garden truck, 5 years; tobacco, 45 years, 1,550 pounds. Other crops average. It has been manured 45 times, 12 loads to the acre.

No. 10. (918-917), Edgerton. Cropped 56 years. The number of crops and estimated yields are as follows: Wheat and oats, 20 years; corn, 10 years, 35 bushels per acre; tobacco, 26 years, 1,500 pounds. It has been manured 26 times, 11 loads per acre.

No. 11. (920-919), Edgerton. Cropped 50 years. The number of crops and estimated yields are as follows: Tobacco, 35 years; small grains, 12 years; oats, 1 year; corn, 1 year; clover, 1 year, average yields. It has been manured 35 times, 13 loads to the acre.

No. 12. (924-923), Edgerton. Cropped 30 years to tobacco, 1,000 pounds per acre. It has been manured 30 times, 15 loads per acre.

No. 13. (928-927), Edgerton. Cropped 18 years. The number of crops and estimated yields are as follows: Tobacco, 9 years, 1,400 pounds; timothy and clover, 6 years, 2 tons; oats. 3 years, 25 bushels. It has been manured 8 times, 25 loads per acre.

No. 14. (942-941), Edgerton. Cropped 52 years. The number of crops and estimated yields are as follows: Wheat, oats, and rye, 7 years; tobacco, 45 years, 1,450 pounds. It has been manured 45 times, 28 loads per acre.

No. 15. (971-970), Albion. Cropped 62 years. The number of crops and estimated yields are as follows: Tobacco, 35 years, 1,500 pounds; corn, 3 years; oats, 1 year; average yields, seeded to clover and clover turned under for tobacco. Earlier crops principally small grains and very little corn. It has been manured 35 times, 23 loads per acre.

No. 16. (997-995), Edgerton. Cropped 37 years. The number of crops and estimated yields as follows: Tobacco, 34 years, 1,400 pounds per acre; grain, average yields. It has been manured 33 times, 17 loads per acre.

The average cropping was 46 years; 30 years to tobacco.

In estimating the amount of phosphoric anhydride removed by crops, it has been assumed that corn, small grains, and timothy remove 20 pounds per acre each year; clover, 25 pounds; sugar beets, 36 pounds; and tobacco, 15 pounds. Analyses in the Station laboratory have shown 0.69 per cent phosphoric anhydride in the leaves and stems of tobacco, and 0.72 per cent in the stalks. An average crop is in round numbers 1,200 pounds of dry matter—leaves and stems. The ratio of leaves and stems to stalks is 1.2 to 1. The stalks at present are usually returned to the tobacco fields, but in the past this

practice was less commonly followed. On the whole, 15 pounds of phosphoric anhydride per acre each year seems a reasonable figure. The manure has been estimated at seven pounds of phosphoric anhydride per load. In estimating the number of pounds of phosphoric anhydride per acre, it has been assumed that the surface eight inches has a weight of 2,000,000 pounds.

Table III gives the per cent of phosphoric anhydride in the virgin and cropped soils, the loss or gain indicated by analyses of the soil, the amount removed by crops, the amount added by manure, and the loss from the soil above that taken by the crop.

TABLE III.—EFFECT OF MANURING ON PHOSPHATE CONTENT OF SOILS, SURFACE EIGHT INCHES.

No.	No. of laboratory sample.	Per cent P_2O_5 in virgin soil.	Per cent P_2O_5 in cropped soil.	Pounds per Acre, Estimated.			
				Excess of P_2O_5 in virgin = — in cropped = +	Taken by crops.	Added in manure and fertilizer.	Loss above crop.
1	513-542	0.09	0.07	— 400	450	3,150	3,100
2	735-734	.11	.18	+1,400	682	5,495	3,413
3	831-830	.15	.14	— 200	1,075	2,310	1,435
4	833-832	.31	.14	—3,400	545	910	3,765
5	848-847	.20	.16	— 800	600	5,670	5,870
6	860-859	.14	.17	+ 600	900	5,152	3,652
7	866-865	.12	.08	— 800	1,010	2,730	2,520
8	887-886	.17	.12	—1,000	1,090	4,200	4,110
9	915-914	.22	.14	—1,600	1,035	3,780	4,345
10	918-917	.13	.24	+2,200	990	2,002	—1,188
11	920-919	.13	.17	+ 800	830	3,185	1,555
12	924-923	.18	.25	+1,400	450	3,150	1,300
13	928-927	.14	.07	—1,400	345	1,400	2,455
14	942-941	.28	.21	—1,400	815	8,820	9,405
15	971-970	.08	.15	+1,400	1,065	5,635	3,170
16	997-995	.20	.20	....	570	3,927	3,357
Average ...		**0.165**	**0.156**	**—200**	**778**	**3,844**	**3,340**

Of the 16 fields, nine show a decrease by analysis, six an increase, while one has remained constant. The average of the 16 fields indicates a loss of 5.4 per cent of that contained in the original virgin soil. It is evident, therefore, that in spite of the large additions of phosphoric anhydride in manure there has been no increase in the soil itself, although the decrease is not so great as in the case of the exhausted soils.

When the phosphoric anhydride added in manure is compared with that removed by crops, it is seen that on the average, almost five times as much phosphoric anhydride has been

added in manure as removed by crops. This indicates an average loss of over 3,000 pounds per acre above that taken by the tobacco and other crops.

Considering both methods of farming, it is evident that tobacco takes less phosphoric anhydride from the soil than do general farm crops, and that the very large quantities of manure applied in the former case, do not add to the store of phosphoric anhydride in the soil. Whereas in general farming, the loss above crops is only eight per cent of the original amount in the soil, in tobacco farming, it is 100 per cent—more than 12 times as much. Even if the figures assumed for the amount removed by crops are low and the figures for the amount added in manure are high, this still means an enormous waste of the most important fertilizing constituent of our soils.

Whether or not the nitrogen and potash added in these very large quantities of manure yield returns sufficient to pay for this waste, is a problem now under investigation in this laboratory. It is also the intention to undertake a study of this loss of phosphoric acid to determine, if possible, whether it has been precipitated in the subsoil, or lost through the drainage water; and if the latter, in what form it is lost. It appears to be possible that this excessive loss from the soil takes place in organic forms which are not precipitated or fixed by the soil. It has been suggested that this loss is due to surface wash, but it would necessitate the removal of a considerable portion of surface soil to account for the enormous loss noted, and since the fields examined are all level there could have been no chance for such an occurrence.

CONCLUSIONS.

1. Crops from nine exhausted fields account for 80 per cent of the phosphoric anhydride lost from the soil of those fields.

2. Crops from 16 heavily manured fields account for 19 per cent of the phosphoric anhydride lost from the soils of those fields.

3. Heavy applications of manure in tobacco cropping result in an enormous loss of phosphoric anhydride. In the 16 fields examined this loss is equal to the total amount originally present in the soil.

II. Phosphate Availability in Its Relation to Soil Acidity.

C. W. STODDART.

In a previous article upon this subject[1] it was shown that acid soils need phosphate fertilizers. This fact was noted not only in the work of other investigators on acid soils but also from field and plant house fertilizer tests on numerous Wisconsin soils. Since the publication of the preliminary paper further tests have confirmed that statement, with one exception, viz.: where a test was made on an acid virgin soil in which no fertilizer need was indicated, as might be expected.

ACTION OF SOIL ACIDS ON PHOSPHATES.

Although there is phosphoric acid present in these soils in sufficient quantity for many crops, it is not available, and hence the soils need phosphate fertilizers. That acid soils do lack available phosphates is a fact, but the question now arises as to a causal relation, if any, between the two conditions; that is, whether lack of the available phosphates is due to the acid condition of the soil. If this is true, it may be explained as follows: The soil acids act upon the readily available phosphates, such as the calcium phosphates, at a more rapid rate than the normal, neutral, or alkaline soil moisture, and when once in solution these phosphates are readily washed out by heavy rains, or are fixed by iron and aluminum compounds—that is, they are precipitated and rendered unavailable as insoluble iron and aluminum phosphates. When there is sufficient lime in the soil to maintain the phosphoric acid in the form of calcium phosphate, the plant is able to obtain enough phosphorus for its use, since calcium phosphate is soluble enough to supply the needs of a growing crop. If it can be shown by chemical

[1] Whitson and Stoddart, 23d An. Rpt. Wis. Expt. Sta., p. 171.

analysis that acid soils contain more iron and aluminum phosphates and less calcium phosphate than do non-acid soils, and particularly if they contain a greater ratio of iron and aluminum phosphates to calcium phosphate, there is evidence in favor of causal relationship between acid soils and lack of available phosphates.

TESTS OF SOLVENTS ON MINERALS.

In order to test this matter it is necessary to find some solvent which will extract the iron and aluminum phosphates and not the calcium phosphate, and vice versa. In selecting solvents which will extract these minerals separately from the soil it is advisable to try them first on pure minerals, although it is well recognized that the action of any solvent on a pure mineral may not be the same on that mineral when it occurs in the soil, since the soil is a complex mixture of various minerals in different stages of weathering, and of organic matter in all forms of decomposition. It is commonly assumed that the principal phosphate minerals occurring in the soils are apatite (calcium phosphate), dufrenite (basic iron phosphate), and wavellite (basic aluminum phosphate).

The mineral samples tested with the various solvents contained in the case of apatite, 39.7 per cent phosphoric anhydride; dufrenite, 19.6 per cent; wavellite, 19.5 per cent. Since precipitated aluminum phosphate is soluble in a solution of sodium hydroxide, this solvent was tried in varying strengths, viz.: 1, 5, and 10 per cent. Three portions of wavellite, 0.2 gram each, were treated with 100 cc. of the different strengths of solvent in a boiling water bath for five hours. The solution was filtered and the phosphoric anhydride determined in the usual manner. The 1 per cent solution extracted 99.4 per cent of the phosphoric anhydride in the mineral; 5 per cent solution extracted 94.3 per cent, as did the 10 per cent solution. Accordingly a 1 per cent solution of sodium hydroxide was chosen for the experiments. Sodium hydroxide free from phosphate was used. To try the effect of the sodium hydroxide solution on the other minerals, 0.2 gram each of dufrenite and apatite were treated with 100 cc. of the solution. Dufrenite yielded 90.4 per cent of its phosphoric anhydride to this solvent, and apatite, 8.4 per cent.

Fraps[1] gives the result of the action of various acid solvents on several kinds of phosphates, minerall and precipitated. From his table it is to be noted that N/5 nitric acid acting at a temperature of 40 degrees C. for five hours extracts 100 per cent of phosphoric anhydride in apatite, 1.5 per cent in dufrenite, and 3.6 per cent in wavellite.

The minerals used by the writer, taking as before 0.2 gram of mineral and 100 cc. of solvent at 40 degrees, gave for apatite 95.4 per cent of phosphoric anhydride extracted, for the dufrenite 4.4 per cent, and for the wavellite 9.4 per cent. Using this same strength of acid in a boiling water bath for five hours, 100 per cent of the phosphoric anhydride in the apatite was extracted 58.9 per cent of the wavellite, and 8.2 per cent of the dufrenite. From these results it can be seen that it is necessary to keep the temperature at 40 degrees during the five hours of extraction.

In using these solvents on the soil it was assumed that there would be extracted, in the case of the sodium hydroxide solution, the iron and aluminum phosphates, but not the calcium phosphate, and in the case of the N/5 nitric acid, the calcium phosphate but not the iron and aluminum phosphates; or at least that there would be extracted proportional parts of the phosphates wherever there might be inclusion of the minerals within the soil grains. In every case, samples which had been passed through a 100–mesh sieve were used.

HISTORY OF SOIL SAMPLES ANALYZED.

Twelve soils were selected, six of them not acid and six of them acid, as shown by the usual litmus paper test. The history of the various soils follows:—

No. 523, Mayville. Cropped 60 years to grains; during the later years a 4-year rotation has been practiced with clover and timothy and manure has been applied. Yields good, and fertility is maintained. Not acid.

No. 270, Blue Mounds. Cropped 60 years to grains. Clover now raised and manure applied so that the yields are good and fertility is maintained. Not acid.

No. 865, Evansville. Cropped 57 years to grains and considerable tobacco. Manured heavily for tobacco, and crops are good. Not acid.

No. 127, Superior. Raised but few crops of wild hay. Fertilizer tests in the plant house showed a slight lack of available phosphates. Not acid.

---

[1] Availability of Phosphoric Acid of the Soil, Jour. Am. Chem. Soc., 28: 824.

No. 61, Stanley. Cropped about 10 years; very poor yields, differing from rest of this region. Plant house test shows need of phosphates. Not acid.

No. 618, Plot 6, Station Farm at Madison. Cropped about 25 years in rotation to corn, oats, seeded to clover, clover and potatoes, and manured on clover sod. Not acid.

No. 293, Twin Bluffs. Cropped 40 years; some wheat, corn, and oats; crops sold off; the soil has been kept up for 20 years. Field test showed need of phosphates. Acid.

No. 736, Afton. Cropped 61 years to grains, a little manure has been applied; oats poor; responded to phosphate in the field. Acid.

No. 852, Evansville. Cropped 50 years to grains, some tobacco; manured for tobacco. Has been badly exhausted; not quite so bad now. Responded to phosphate in the field. Acid.

No. 246, Onalaska. Cropped about 40 years to corn and oats; little or no clover; badly exhausted. Field tests showed need of phosphates. Acid.

No. 277, South Wayne. Cropped 60 years, first to wheat, then mixed farm crops with some stock kept on the place; crops all removed; is badly depleted. Field test showed need of phosphates. Acid.

No. 297, Black Earth. Cropped 20 years in rotation and fairly well managed; it is in fair state of fertility. Field tests showed need of phosphates. Acid.

It is to be noted that all these soils have been cropped from 10 to 60 years, except one which has been under cultivation but a few years. One soil, No. 127, is a heavy red clay, the others are loams with varying amounts of sand and clay.

METHODS OF ANALYSIS.

Twenty-five grams of soil were treated with 250 cc. of solvent in a flask fitted with a ground glass stopper carrying a condenser. For the sodium hydroxide solvent the flask was set in a boiling water bath and shaken every hour. At the end of the five hours it was allowed to cool, and filtered through a dry filter, twice if necessary, to remove the clay.

The sodium hydroxide extracted some of the humus in the soil, so that the liquid was black in color. It was necessary to remove the organic matter before determining the phosphoric anhydride extracted by sodium hydroxide from the minerals. Accordingly duplicate portions of 100 cc. each were placed in test tubes, made slightly acid with 2 cc. concentrated hydrochloric acid, placed in a centrifuge and whirled at a speed of about 1,200 revolutions per minute for 15 minutes. The slimy organic matter, or "humic acid," as it is popularly called, was firmly packed in the bottom of the test tube by this treatment, and the clear, supernatant liquid could be readily decanted through a dry filter. Aliquot portions of the filtrate were then oxidized with bromine to remove some organic matter which

remained in solution. It is unfortunately not possible to throw all of the organic matter out of solution by acid, but the amount left is very small, and the phosphoric anhydride in this organic matter would be practically nil, since, as may be seen later, the phosphoric acid even in a true humic extract is very small in amount.

After the extraction of the organic matter the solution is acidified with nitric acid, and evaporated to dryness, silica dehydrated, then taken up with nitric acid and water, and filtered. From this point the usual methods for determining phosphoric acid were employed. It may be well to state that, although the gravimetric method was used wherever possible, in many cases the amount of phosphoric acid was so small that this method was not feasible. In such cases the yellow precipitate was dissolved in standard sodium hydroxide solution and the excess titrated with standard nitric acid. While it is well to note that the volumetric method is apt to give high results, it has been found that working with very small amounts the method is reasonably accurate, certainly much more so than the gravimetric method where it would be necessary to weigh a precipitate of considerably less than one milligram in weight.

Where the soils were treated with N/5 nitric acid the temperature of the water bath was kept at 40 degrees for five hours, the flasks being shaken every hour. After filtering off the soil the clear filtrate was found to contain a very small amount of organic matter dissolved by the nitric acid. The solution accordingly was made slightly alkaline with sodium hydroxide, oxidized with bromine, acidified with nitric acid, evaporated to dryness, silica dehydrated, etc., as before.

PHOSPHORIC ANHYDRIDE CONTENT OF HUMUS.

In addition to the above mentioned determinations, it was thought advisable to make a brief study of the phosphoric acid combined with the humus. It is well known that the humus of the soil,—that black, waxy coating of the soil grains,—contains in chemical combination some phosphoric acid, as well as other inorganic compounds. The question had arisen as to the composition and amount of humus in well drained, cropped, acid soils as compared with non-acid soils. The only method available for this work was the usual extraction with ammonia after

treatment with hydrochloric acid; but in this method there are certain weak points to be avoided.

The determination of humus by loss on ignition of the dried extract is open to two objections: First, the heating causes loss of zeolitic water from the clay which remains in suspension in the solution and cannot be removed by ordinary filtering; and second, even if the clay were removed, the result would represent only the volatile compounds in the humus and not the important ash constituents which are certainly a part of the humus.

It has been possible to remove the clay by filtering through an unglazed porcelain filter, but this removes some of the organic matter with the clay, since the humus extract is not in all respects a true solution but has some properties of a colloid.

After the clay is removed the humus must be precipitated by an acid, since the ammonia extracts some of the phosphoric acid from the minerals in the soil. Fraps[1] shows that samples of apatite, dufrenite, and wavellite extracted by ammonia yielded 3 per cent, 13 per cent, and 44 per cent of phosphoric anhydride, respectively. He used material corresponding to 0.1 gram phosphoric anhydride shaken with 2,000 cc. of 4 per cent ammonia at intervals for 24 hours and then filtered. The minerals used by the writer when treated in 0.2 gram portions with 500 cc. of 4 per cent ammonia for 24 hours with shaking and then 12 hours at rest, yielded approximately 1 per cent for apatite, 3 per cent for dufrenite, and 55 per cent for wavellite. These results show that it is unsafe to determine the phosphoric acid in the ammoniacal extract and call it all humic phosphate.

Fraps, in the article just referred to, makes use of ammonium sulphate to flocculate the clay in the ammoniacal extract of the soil, and this method was pursued in the following experiments. Hydrochloric acid was used to precipitate the humus, since this acid has been found[1] to give better results than nitric acid. The filtrate is less colored by soluble organic matter. The humus is not completely precipitated even by hydrochloric acid, but is practically so.

---

[1] The Ammonia-Soluble Phosphoric Acid of the Soil, Am. Chem. Jour., **39**: 580.
[1] Unpublished results of H. L. Walster, Soils Dept., Wis. Expt. Sta.

METHOD OF DETERMINING PHOSPHORIC ANHYDRIDE IN HUMUS.

The method as used in this work was to treat 25 grams of soil in a glass stoppered bottle with 400 cc. of 1 per cent hydrochloric acid for one hour, shaking constantly in a mechanical shaker. Then it was filtered through a Büchner funnel on which had been placed a hardened filter paper. The soil was washed free from chlorides and transferred to a liter Erlenmeyer flask with 500 cc. of 4 per cent ammonia and shaken at intervals for 24 hours. At this point 25 cc. of ammonium sulphate solution, containing 10 grams of the solid, were added, the mixture shaken and allowed to stand over night. When filtered through ordinary filter paper the filtrate was absolutely free from clay, the latter containing little, if any, gelatinous organic matter, and the filtration proceeded rapidly. For the determination of humus 50 cc. were placed in a heavy test tube, acidified with 8 cc. concentrated hydrochloric acid and whirled in the centrifuge. The supernatant liquid was decanted through a weighed Gooch crucible, the humus transferred to the Gooch, washed with 1 per cent hydrochloric acid, dried at 105 degrees and weighed.

The humic phosphate was determined on an aliquot portion of the extract, treated in test tubes with hydrochloric acid, whirled in the centrifuge, filtered, and washed. The precipitate was dissolved through the paper with 1 per cent sodium hydroxide solution, the paper washed clean with sodium hydroxide solution, and the organic matter oxidized with bromine, then acidified with nitric acid, evaporated dry, the silica dehydrated, and the phosphoric anhydride determined volumetrically, since the amount of yellow precipitate was very small.

Some preliminary trials of this method where the filtrate from the humus, as well as the humus, were analyzed for phosphoric anhydride, showed that there were about four times as much phosphoric anhydride in the filtrate as in the precipitate. This represents for the most part the phosphoric anhydride extracted by ammonia from the minerals of the soil.

Table IV gives the percentages of the total phosphoric anhydride, phosphoric anhydride extracted by 1 per cent sodium hydroxide solution, phosphoric anhydride extracted by N/5 nitric acid, phosphoric anhydride in the humus, and the humus,

TABLE IV.—PERCENTAGE OF PHOSPHORIC ACID AND HUMUS.

Soils not Acid.

No. of sample.	Total P_2O_5.	P_2O_5 by NaOH.	Per cent. of total.	P_2O_5 by HNO_3.	Per cent. of total.	Humic. P_2O_5.	Per cent. of total.	Humus.	Humic P_2O_5 per cent. of humus.	Years cropped.	Locality.
523	0.14	0.039	27.86	0.025	17.86	0.013	9.28	0.72	1.81	60	Mayville.
270	.18	.054	30.00	.023	12.78	.007	3.89	1.10	.64	60	Blue Mounds.
865	.08	.046	57.50	.035	43.75	.011	13.75	.51	2.16	57	Evansville.
127	.15	.039	26.00	.010	6.67	.009	6.00	.19	4.74	3	Superior.
61	.19	.080	42.10	.010	5.26	.022	11.58	.69	3.19	10	Stanley.
618	.18	.030	16.67	.063	35.00	.014	7.78	.63	2.22	25	Madison.
Average	**0.153**	**0.048**	**33.35**	**0.027**	**20.22**	**0.012**	**8.71**	**0.64**	**2.46**	**35**	

Soils Acid.

No. of sample.	Total P_2O_5.	P_2O_5 by NaOH.	Per cent. of total.	P_2O_5 by HNO_3.	Per cent. of total.	Humic. P_2O_5.	Per cent. of total.	Humus.	Humic P_2O_5 per cent. of humus.	Years cropped.	Locality.
293	0.12	0.038	31.67	0.012	10.00	0.007	5.83	0.28	2.50	40	Twin Bluffs.
736	.07	.053	75.21	.027	38.57	.008	11.43	.67	1.19	61	Afton.
852	.13	.073	56.15	.009	6.92	.011	8.46	1.19	.92	50	Evansville.
246	.12	.014	11.67	.011	9.17	.011	9.17	.30	3.67	40	Onalaska.
277	.14	.018	12.86	.007	5.00	.009	6.43	.17	5.29	60	South Wayne.
297	.17	.054	31.76	.014	8.24	.019	11.18	1.51	1.25	20	Black Earth.
Average	**0.125**	**0.041**	**36.63**	**0.013**	**12.98**	**0.011**	**8.74**	**0.68**	**2.47**	**45**	

TABLE V.—HUMUS AND PHOSPHORIC ACID IN HUMUS.

Twelve soils in the order of their humus content.

Humus............	1.51	1.19	1.10	0.72	0.69	0.67	0.63	0.51	0.30	0.28	0.19	0.17
P_2O_5 in humus..	1.25	0.92	0.64	1.81	3.19	1.19	2.22	2.16	3.67	2.50	4.74	5.29

all expressed on the basis of dry soil; then the percentages of phosphoric anhydride extracted by sodium hydroxide, by nitric acid, and in humus, expressed on the basis of total phosphoric anhydride: and finally the humic phosphoric anhydride expressed on the basis of humus, besides the arithmetical averages of the different results.

DISCUSSION OF RESULTS.

The averages show that, while acid soils do not contain more iron and aluminum phosphates than do non-acid soils, they do contain a larger percentage of their total phosphoric acid in the iron and aluminum form, and in addition a considerably greater ratio of iron and aluminum phosphates to calcium phosphate: 3 to 1 for acid soils, and about 1½ to 1 for non-acid soils.

Turning now to the phosphoric acid soluble in N/5 nitric acid, it is seen that considerably more is extracted from the non-acid soils than from the acid soils. In other words, the non-acid soils contain more calcium phosphate than do the acid soils. This is to be expected if soil acidity is the cause of the lack of available phosphates.

Aside from this consideration, the figures show another interesting fact. It will be remembered that two of the non-acid soils responded to a phosphate fertilizer, Nos. 61 and 127. All of the acid soils have shown the lack of available phosphates. The average per cent of phosphoric acid soluble in nitric acid of the four soils which do not need phosphate, is 0.036 per cent; and of the eight soils which do need phosphate is 0.012 per cent: three times as much calcium phosphate in non-responsive as in responsive soils.

Dilute nitric acid has been used by investigators with more or less success as an indicator of soil needs and the results here given show the value of N/5 nitric acid in determining the availability of phosphates of the soil. It seems reasonable to suppose that this is because the nitric acid dissolves out but little more than the calcium phosphate, and if calcium phosphate exists in too small amount the plant suffers for lack of phosphorus. Ordinarily a chemical analysis of the soil is of very little value in ascertaining the fertilizer requirements of

a soil, inasmuch as the nutrition of the crop depends on the rate at which the fertilizing elements become available, and not upon the total amount present at any one time; but from these figures, it appears that the amount of calcium phosphate in a soil gives a very excellent idea as to the requirements of a soil with reference to phosphoric acid. In other words, there is a strong probability that the value of N/5 nitric acid as an indicator of soil needs lies in the fact that it determines the amount of calcium phosphate in the soil, and does not merely imitate the solvent action of plant roots. From the results obtained in this work it can be stated that, for Wisconsin at least, if a soil contains less than 0.015 per cent of phosphoric acid soluble in N/5 nitric acid, it will respond to a phosphate fertilizer.[1]

Considering Table I again, it is to be noted that the humus content of the two sets of soils is about the same and the phosphoric anhydride in the humus is also about the same in both acid and non-acid soils, indicating that the reaction of the soil does not affect the accumulation of phosphoric acid in the humus.

TABLE VI.—HUMUS AND PHOSPHORIC ACID IN HUMUS. AVERAGED IN GROUPS OF THREE.

Humus	1.[illegible]7	0.48	0.6[illegible]	0.21
P_2O_5 in humus	0.93	2.06	2.68	4.17

If, however, the soils are arranged in the order of their humus content from highest to lowest, together with the corresponding percentages of phosphoric anhydride expressed on the basis of humus, it will be seen in a general way that as the amount of humus decreases the percentage of phosphoric anhydride in the humus increases.[1] (See Table V.)

[1] In this connection it is interesting to note the following quotation by Harry Snyder from Bul. No. 102, Minn. Expt. Sta., p. 36: "In all the trials, with the one exception noted, where the phosphate fertilizer failed to give an increase, the soil contained over 150 parts per million of phosphoric acid soluble in fifth normal nitric acid." The two similar conclusions were drawn independently and from work done on different soils.

[1] C. G. Eggertz, Centbl. Agr. Chem., 1906, 35: 793, states that in ordinary soils the organically bound phosphoric acid increases as the humus content increases.

On the other hand E. Coppenrath, Landw. Vers. Stat. 69: 28, footnote, maintains that 6 to 10 times as much phosphoric acid is dissolved by ammonia from sand and sandy loams as from lime, loam, and clay soils, although the last three

Arranging the soils in groups of three, and averaging the percentages thus expressed, this fact is brought out more strikingly. (See Table VI.) These results suggest the possibility that phosphorus in humus is not made available to plants as the humus decomposes; but rather that the phosphorus once in the humic form is unavailable to plants. This point is to be tested on comparable virgin and cropped samples of soil, and in addition further work is contemplated on the changes taking place in a soil during its period of cropping. Acid and non-acid soils will be used, these same soils so far as possible, but the study will be made of the differences that exist in the phosphate compounds between the virgin and the cropped samples.

CONCLUSIONS.

1. Acid soils lack available phosphates.

2. Soil acidity seems to cause a lack of available phosphates, since acid soils contain a higher percentage of their total phosphoric acid in iron and aluminum form and less calcium phosphate than do non-acid soils, and particularly a greater ratio of iron and aluminum phosphates to calcium phosphate. This does not mean that non-acid soils may not be lacking in available phosphates due to some other cause.

3. The figures on humus and phosphoric anhydride in humus show an interesting variation, suggesting that humic phosphorus may be unavailable to plants.

4. The N/5 nitric acid is an excellent indicator of soil needs with respect to phosphates, due to the fact that it determines the amount of calcium phosphate in soils. If a soil, in Wisconsin at least, falls below 0.015 per cent of phosphoric acid soluble in N/5 nitric acid, it will respond to phosphate fertilizer.

---

soils had considerably more humus. His results for phosphoric acid and humus are as follows:

Soil.	I	II	IV	V	VI
P_2O_5 per cent	0.016	0.029	0.003	0.005	0.019
Humus	1.07	1.77	2.17	4.[illegible]5	3.32

In neither case is it stated just how the determination of humus and organic phosphoric acid was made. Hence their results may not be strictly comparable either with each other, or with the above.

The Efficiency, Economy and Physiological Effect of Machine Milking[1]

F. W. WOLL AND G. C. HUMPHREY

One of the great objections to dairying is the difficulty of securing efficient help to do the milking. This difficulty has doubtless materially retarded the development of the dairy industry, and in many cases caused farmers to keep fewer cows than they otherwise would. Any possibility of milking cows by machinery therefore appeals strongly to the dairy farmer and all interested in the dairy industry. Inventors have been at work on this problem for a century and the patent-office records of this and other countries contain a vast number of mechanical devices for milking cows. Several machines were placed on trial on dairy farms in years gone by, with results, in some instances, that would seem to justify the belief that the time had come when it would no longer be necessary to milk cows by hand. Trials under ordinary farm conditions for a season or two sufficed to show, however, that with but a few exceptions, the earlier milking machines were not practical and are now only of historical interest.

The milking machines which have been placed on trial by inventors in the past are of two types, viz., one being operated by pressure on the teats and the lower part of the udder, and the other, by suction, either without or with manipulation of the udder, in imitation of the sucking of the calf. The machines

[1] The manuscript for this bulletin was completed in November, 1908. The delay in publication has been the result of a change in the method of issuing the publications of this Station and of the pressure in the State Printer's Office during the session of the Legislature.

on the market in this country at the present time are of the latter type.[2]

The B. L. K. milking machine[3] has been on trial by the manufacturers for over four years and by practical dairymen for two or more years. Many enthusiastic reports concerning its operation have been published in the dairy and agricultural journals during the past two years, and considerable practical experience has accumulated, that would seem to justify the belief that the era of machine milking has finally come through the introduction of this machine. Under these conditions, it was believed that a careful study of this and possibly other machines for milking cows ought to be made at this Experiment Station, in order that we might be placed in a position to furnish dairy farmers with first-hand, reliable information as to the practicability and general value of this method of milking under modern conditions of dairying.

The initiative in the matter was taken by E. H. Farrington, in Charge of Dairy Husbandry at this station who made the arrangements with the manufacturers for a trial of one of their machines in the University dairy herd, and in October, 1906, the machine was installed in the dairy barn. The installation was in charge of G. H. Benkendorf, Assistant in Dairy Husbandry, who has also acted as expert mechanician during the progress of the trials. W. E. Markey was appointed assistant in charge of the machine, and has attended to the running of the machine, and the milking, weighing, and sampling of the milk of the cows on the experiments. Mr. Markey was also entrusted with a large amount of work connected with the recording and compiling of the data for the different cows included on the experiments, and the value of the results so far obtained is due to a large extent to the conscientious, painstaking manner in which he discharged his various duties. Roy T. Harris, Assistant in Dairy Tests, has likewise rendered efficient aid during the progress of the experiments and in the compilations of

[2] An historical sketch of milking machines patented in this country is given in Bul. 140 of the Kan. Exp. Sta., "Milking Machines," by Oscar Erf; see also Arb. Deut. Landw. Gesell., Heft 37, Prüfung d. Thistle Melk-Maschine, by B. Martiny, and Bul. 113, Pa. Dept. of Agr., "Methods of Milking," by F. W. Woll.

[3] The Burrell-Lawrence-Kennedy Cow Milker manufactured by D. H. Burrell & Co., Little Falls, N. Y. See Appendix for a full history of this machine.

tables and other data required in the preparation of this report. Credit is also due to C. J. McComb, Dairy Herdsman, and his successor, E. W. Fox, for assistance rendered in the conduct of the experiments and for the painstaking manner in which they cared for the herd.

The bacteriological studies of the milk and of the cleanliness of the machine were made by E. G. Hastings, Agricultural Bacteriologist and assistants, and Dr. A. S. Alexander, Veterinarian of this Station, investigated the effect of machine-milking on the teats and udders of the cows, and on their health. Reports of the latter two phases of the subject will be found in this bulletin.

PLAN OF THE EXPERIMENTS

The plan of the experiments included a careful and detailed study of

(1) The efficiency of machine-milking with cows of different ages, stages of lactation, disposition, and conformation of udders and teats;

(2) The economy of machine-milking as compared with hand-milking;

(3) The influence of the machine on the bacteria of the milk and on its keeping quality;

(4) The influence of the machine on the health of the cows, with periodic veterinary examinations of the udders and teats of the machine-milked cows;

(5) The experience with machine-milking in other dairy herds in this state.

The experiments here described were commenced October 31, 1906, and continued for 20 months. The period covered by the trials therefore includes two winter and two spring seasons, thus permitting a study of the work of the machine during varying conditions as to lactation periods, summer and winter methods of feeding and managing the herd, handling of milk, etc. The methods practiced in feeding and managing the cows in the University dairy herd have been described in Bulletin No. 167 of this Station "The University Dairy Herd; Management and Records, 1907–1908," to which reference is here made for information along this line.

THE MILKING MACHINE USED

In the B. L. K. milking machine used in this investigation the air is partially exhausted by means of a vacuum pump from a tightly covered milk pail (or "milker") which is connected by a rubber hose and stanchion cocks with a system of piping extending in front of the cow stalls; the milk pail is connected with the cow's udder by means of a rubber tube and so-called "teat-cups" and "mouth-pieces" which fit over each teat. Through the pull of the partial vacuum in the milk pail, the milk is drawn into the pail.

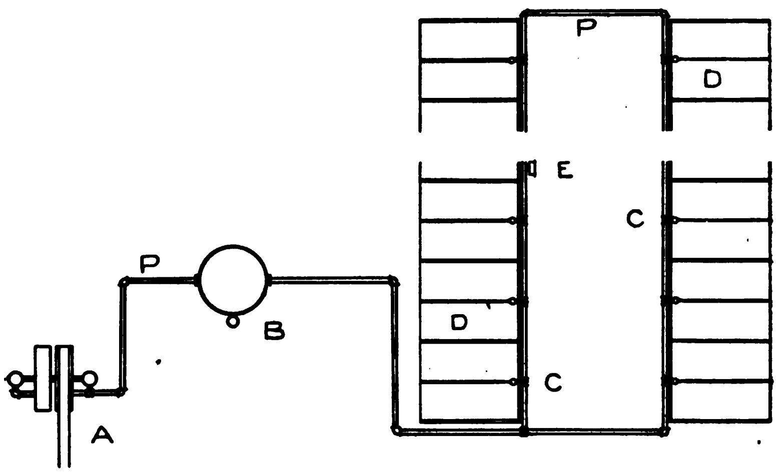


Figure 1.—Plan of installation of the milking machine in the University dairy barn. The milking is done by partial exhaustion of the air from tightly covered pails. A partial vacuum is produced by the vacuum pump, A, and the vacuum tank, B, maintains a uniform vacuum of 15 to 16 inches which is indicated by the vacuum gauge, E. The pails are connected by a rubber hose with the stanchion cocks, C. The pails are placed between each two cows in the stalls, D, and a rubber hose, teat cups and mouth-pieces connect the pails with the teats of the cows. The pulsating device subjects the teats to an intermittent suction which draws the milk into the pail.

Experience early taught the inventors that continuous suction on the teats during the process of milking is injurious to the cow, and this difficulty has been overcome in the machine under trial by producing intermittent suction, through an ingenious mechanical device which relieves the suction at rapid intervals (about 60 times a minute), and thus prevents any abnormal strain on the teats or the udder of the cow.

For a description of the various parts of this milking machine see the printed matter published by the manufacturers which

includes discussions of the method ot operation, prices, etc. The illustrations and diagrams presented herewith are designed to give a clear idea of the working of the machine.

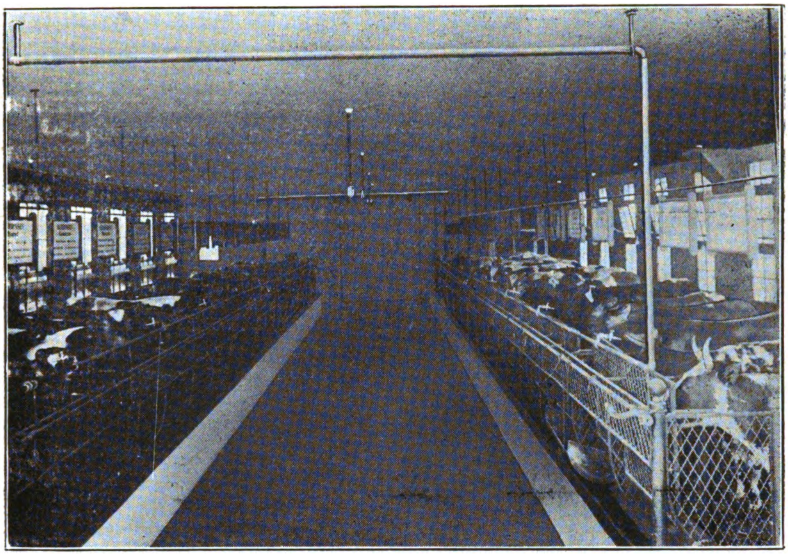


Figure 2.—Interior view of the University dairy barn. The system of piping extends in front of each row of stalls with stanchion cocks between every two cows.

CONDUCT OF EXPERIMENT

The machine was installed in the University dairy barn in the following manner: The 4½ inch cylinder vacuum-pump and the vacuum tank provided with a safety valve and vacuum gauge were placed in the basement of the barn, the latter being connected with the stable and stalls above by iron piping, as will be seen in the diagram. To make it possible to place the pails between the cows and to attach them conveniently to the stanchion cocks along the vacuum pipe in front of the cows, the swinging partitions of the iron stalls were fixed so as to be removed each time the cows were milked. A 3 H. P. electric motor, located in the basement of the barn and connected with the city current of 500 voltage, operated the machine.

The experiment was originally planned to include 20 cows, separated into two lots as uniform as possible as to breed, age, weight, stage of lactation, and production of milk and butter

fat. The one lot was to be milked by machine, and the other by hand by the regular attendants. Other conditions having a bearing upon the production of the cows on the experiment were to be maintained as nearly uniform as possible throughout the experiment, and care was especially taken to avoid radical changes in the feed of the cows that would tend to influence

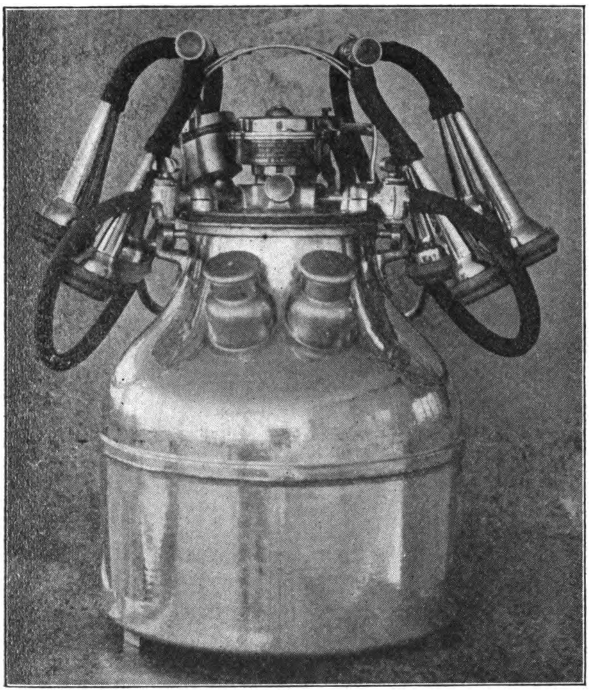


Figure 8.—The improved style of pail for the B. L. K. milking machine used in the later stages of the experiments herein described.

their production in one way or another. It was soon found, however, that we had not been successful in securing uniform lots, since the production of the cows after less than two months varied considerably, without regard to the method of milking practiced, and instead of making comparisons of lots of 10 cows each, we have, therefore, had to consider the effect of machine-milking mainly on the production of individual cows.

The machine-milking was preceded by a two weeks' preliminary period, during which time butter fat tests of the separate milkings of all the cows were made. The machine-milking

of the cows was commenced October 31, 1906, and was continued with such cows as were available until July 1, 1908. Owing to the drying-off or freshening of cows in the herd, the number of machine-milked cows has varied during the progress of the experiments from five to 16 at a time. Tests of the percentage of butter fat in the separate milkings of the cows on the experiment were continued for two weeks after the machine-milking began, and weekly composite samples were tested in

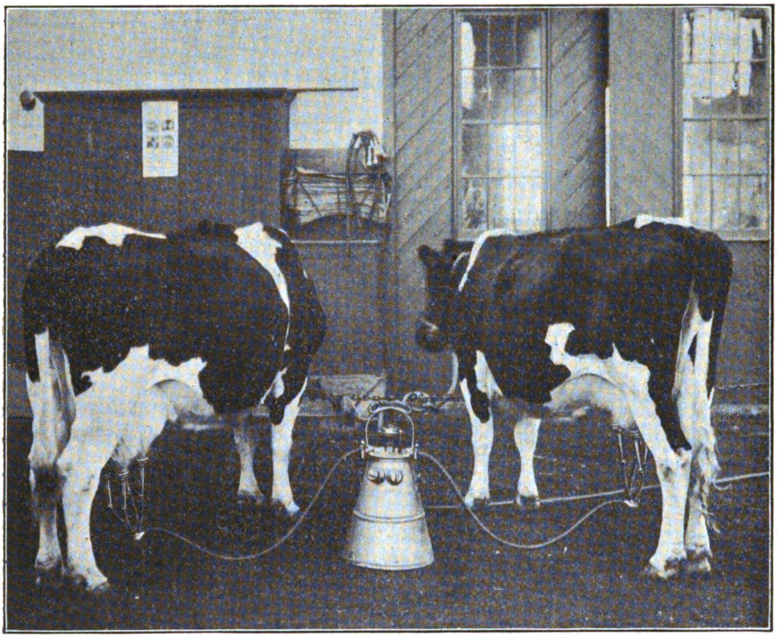


Figure 4.—Old style of B. L. K. milking machine in operation, showing method of adjustment to udders of two cows.

duplicate from that time on. Each cow's milk was weighed throughout the experiments, the milk pails used being provided with partitions, so that the milk of each of the two cows milked at a time could be kept separately, and weighed and sampled by itself.

The machine-milked cows were stripped by the attendant as soon as they did not give down any more milk to the machine. The covers of the milk pails are provided with two glass tubes intended to show when the milking is completed. Some of the milk will, however, remain in the rubber tube after the machine

no longer brings down any milk; this flows back and forth in the tube so that one may easily be deceived if the glass tubes are depended upon altogether to show when the milking machine does not draw any more milk. The only way to tell this definitely is, therefore, to feel of the udder whether or not milk is still coming down. When such is not the case the teat cups are removed and the milking finished by manipulation and stripping, as directed in the circulars issued by the manufacturers.

The strippings were weighed during the whole of the experiment and tested during the first two and the last week of the first 6-month period, and also shortly before and after the cows were let out on pasture in the spring. The ratios obtained for the fat contents of the machine-drawn milk and the strippings for each cow during these weeks agreed closely and were therefore used for calculating the amount of fat in the strippings during the intervening weeks of the experimental period. By this method the percentage of total fat contained in the strippings could be estimated with considerable accuracy.

COWS USED ON THE EXPERIMENTS

The following table gives the names of 29 cows that have been machine-milked during the progress of this investigation; the length of time each cow was machine-milked, the dates of freshening and drying-off, and other facts having a bearing on the production of the cows are also given in the table.

The instructions of the manufacturers as to the operation of the milking machine were carefully adhered to in these experiments, with the exception that visitors were not always excluded from the stable during the time of milking, as directed. It was found impracticable to do this, owing to the interest in the experiments taken by students and by the numerous visitors to this college, many of whom came for the sole purpose of seeing the milking machine and studying its operation in the herd. The cows in the University dairy herd are, however, accustomed to students and strangers passing through the dairy barn and inspecting the herd every day; for this reason it is believed that the rule of the manufacturers with regard to exclusion of visitors at the time of milking did not need to be strictly enforced in the case of this herd. There is, at least, no evidence that the cows were in any way annoyed by the presence of visitors at the

time of milking, as would doubtless be the case with many other herds. In all other respects the milking machine was, as we believe, placed under as favorable conditions as could possibly be found on any dairy farm, and the fact that the machine was at all times given the most careful attention, relative to keeping all parts in a cleanly condition and in perfect repair, should be especially emphasized. The favorable results obtained in the experiments were, no doubt, to a large extent due to this fact; this should be borne in mind by those who read this bulletin with the view of deciding whether or not they will install a milking machine in their dairy barns.

TABLE I.—LIST OF COWS ON THE EXPERIMENTS.

Name of cow.	Breed.	Age Nov 19, 1907.	Weight, lbs.	Machine milked. Dates.		Machine milked. No. of weeks.	Freshened.	Dry.
Laura	J.*	13	939	Oct. 31,06	Mar. 23,07	20	Apr. 26,06	Mar. 23,07
Do	......	......	......	May 8,07	Aug. 13,07	14	May 5, 7	....
Double Time	J.	9	946	Oct. 31,05	Jan. 7,08	62	Sept. 14,05 May 11,08	Jan. 14,08
Perchance	J.	8	993	Oct. 31,05	May 28,07	30	Sept. 18,06	Nov. 13,07
Do	......	......	1,054	Dec. 18,07	June 30,08	28	Nov. 30,07	....
Just in Time	J.	5	889	Oct. 31,06	Aug 13,07	41	July 7,06	Aug. 31,07
Do	......	......	1,004	Nov. 13,07	June 30,08	33	Sept. 25,07	....
Jewel	J.	3	925	Mar. 23,07	Oct. 2,07	26	Dec. 2,06	Nov. 13,07
Do	......	......	......	Dec. 18,07	June 30,08	28	Nov. 30 07	....
Broadway	J.	10	972	Mar. 1,07	May 23,07	13	Mar. 10,06	June, 07
Do	......	......	......	Nov. 13,07	June 30,08	33	Oct. 22,07	....
Macella	J.	8	1,001	Nov. 13,07	June 30,08	33	Oct. 23,07	July 31,08
Goodwin	J.	2	826	Nov. 13,07	June 30,08	33	Nov. 3,07	....
Sadie	J.	4	992	Feb. 20,08	June 30,08	19	Oct. 9,07	July 31,08
Dorine	G.	7	1,078	Oct. 31,06	Nov. 12,07	54	June 23,06	Nov. 12,07
Do	......	......	1,160	Jan. 29,08	June 30,08	22	Jan. 16,08	....
Floradora	G.	6	1,075	Oct. 31,06	Aug. 7,07	40	May 3,06	Sept. 26,07
Jessie	G.	3	928	May 9,07	June 30,08	......	May 1,07	July 27,08
Queen	G.	4	841	Nov. 13,07	June 30,08	33	Oct. 7,07	....
Countess	G.	4	937	May 30,07	Sept. 25,07	17	Dec. 29,06	Oct. 1,07
Hannah	G.	4	958	May 30,07	Nov. 26,07	25	Oct. 13,06	Dec. 3,07
Cozie	G.	8	898	Nov. 13,07	Dec. 10,07	4	Oct. 5,07	....
Alma	H.	12	1,098	Oct. 31,07	Dec. 11,06	6	Mar. 12,06	Dec. 18,06
Ormsby	H.	4	1,080	Oct. 31,06	Apr. 30,07	26	Sept. 18,06	....
Josephine	H.	6	1,194	Oct. 31,06	May 14,07	28	May 5,06	....
Johanna	H.	6	1,163	Oct. 31,06	Dec. 11,06	6	Dec. 7,05	Dec 18,07
Maggie	H.	10	1,267	Dec. 12,06	Oct. 8,07	43	Oct. 1,06	Oct. 13,07
Do	......	......	1,315	Dec. 18,07	June 30,08	28	Dec. 3,07	....
McGeoch	H.	8	1,375	Mar. 1,07	July 9,07	19	Jan. 8,07	....
Maxie	H.	5	1,043	Mar. 1,07	Oct. 29,07	35	Nov. 17,06	Nov. 2,07
Do	......	......	1,132	Dec. 18,07	June 30,08	28	Dec. 7,07	....
Aggie	H.	2	968	Feb. 26,08	June 30,08	18	Nov. 30,07	....
Kate	H.	3	1,041	May 9,07	Nov. 5,07	26	Feb. 24,07	....
Christina	A.	9	950	Dec. 12,06	Aug. 13,07	35	Nov. 3,06	Aug. 24,07
Do	......	......	1,024	Feb. 20,08	June 30,08	19	Sept. 30,07	....
Priscilla	A.	9	975	Nov. 13,07	Jan. 14,08	9	Feb. 20,07	Jan. 26,08
Do	......	......	......	Apr. 22,08	June 30,08	10	Mar. 21,08	....
Adelaide	A.	8	950	Nov. 13,07	Jan. 14,08	9	Mar. 22,07	Jan. 27,08
Do	......	......	......	Apr. 22,08	June 30,08	10	Mar. 20,08	....
Clara	B.S.	10	1,214	Mar. 1,07	June 4,07	14	Apr. 19,06	June, 07

*J=Jersey; G=Guernsey; H=Holstein; A=Ayrshire; B. S=Brown Swiss.

EFFICIENCY OF MACHINE-MILKING UNDER VARYING CONDITIONS

In studying the question of the influence of machine milking on the milk secretion of cows, we may consider,

1. Its immediate effect on the yield of milk and butter fat, and
2. Its effect on the milk secretion for extended periods.

While the latter effect of machine milking is of fundamental importance in determining the success of machine milking, and is, therefore, by far more important than the former, it is of interest to know how machine-milking affects the secretion of the cows during the period immediately following the change in the method of milking. The results obtained in these trials bearing on this phase of the question will be considered at this point, so that readers may know what to expect with regard to the operation of the milking-machine during the first few weeks following the installation.

IMMEDIATE EFFECT ON MILK SECRETION

It is well known that some milkers are able to obtain more milk from certain cows than others, and that after a cow has once become accustomed to a milker, a change is generally detrimental to her production. It may be expected, therefore, that the immediate effect of changing from hand to machine-milking will be a decrease in the production of milk and butter fat. By compiling the yields of the cows during the first three weeks when they were machine-milked and calculating the average results for the cows whose production during these periods was comparable, we obtain the figures for 24 cows (27 different trials) presented in Table II. For the sake of judging whether or not these results are abnormal, or can be fairly accounted for by the change in the system of milking practiced, similar data have been compiled for the same cows for the two weeks before the change in the method of milking occurred.

It will be noted from the average results here given for all the cows included on the trials which furnish comparable data as to the immediate influence of the change from hand to machine-milking, that the average weekly yield of the milk for the

TABLE II.—IMMEDIATE EFFECT OF A CHANGE TO MACHINE-MILKING ON MILK SECRETION.

	Average (27 trials).	Difference.	Average for machine milking.	Trials showing. Gain.	Loss.	No difference.
Weekly yield of milk per cow, lbs.						
1. Hand	176.8	....	....	....	....	....
2. Hand	173.7	—3.1	....	11	16	....
3. Machine	166.7	—7.0	....	9	18	....
4. Machine	160.8	—5.9	—4.8	10	16	1
5. Machine	159.4	—1.4	....	10	17	....
Weekly yield of butter fat per cow, lbs.						
1. Hand	7.46	....	....	....	....	....
2. Hand	7.17	— .29	....	6	21	....
3. Machine	6.77	— .40	....	6	21	....
4. Machine	6.60	— .17	— .25	9	17	1
5. Machine	6.43	— .17	....	10	17	....
Average per cent fat in milk.						
1. Hand	4.22	....	....	....	....	....
2. Hand	4.13	— .09	....	9	16	2
3. Machine	4.06	— .07	....	11	15	1
4. Machine	4.10	+ .04	— .03	16	10	1
5. Machine	4.03	— .07	....	12	14	1

27 trials (with 24 different cows) during the last two weeks of hand milking was 176.8 and 173.7 pounds per cow, a decrease of 3.1 pounds. During the first three weeks of machine milking the corresponding figures were 166.7, 160.8, and 159.4 pounds, a decrease of 7.0, 5.9, and 1.4 pounds for the three respective weeks, or on the average 4.8 pounds. There was, therefore, a somewhat greater decrease in the weekly flow of milk during the period of machine-milking considered than that immediately preceding the change in the method of milking. The table shows that but slight variations occurred in the number of cows gaining or losing in milk during the hand or the machine-milking periods.

Some 11 cows gained and 16 lost in milk from first to second weeks of hand-milking, against nine gaining and 18 losing from second week of hand-milking to first week of machine-milking, which figures did not change materially during the following two weeks. The data for the production of butter fat and for the average quality of the milk produced on these trials, which are given in the table, show, in general, similar relations as those just stated for the milk yield and need no further discussion here.

The conclusion seems warranted that a change from hand-milking to machine-milking is likely to be accompanied by a decrease in the production of the cows during the first few weeks of machine-milking, but this does not, as a general rule, appear to be marked and is perhaps no greater than often results from a change in hand milkers.

EFFECT OF CONTINUED MACHINE-MILKING ON MILK SECRETION

The most important question as to the practicability of machine milking is whether or not cows can be milked satisfactorily by this method for an extended period of time. The results obtained in this investigation furnish a vast amount of material that has a bearing on this point and should enable one to form a judgment with regard to this question. Since there can be no means of comparison between hand and machine-milking for the same cows at the same time, the evidence on this point must necessarily be circumstantial and must be sought by a study of the rate of decrease in the production of the cows for the periods when they were milked by machine, and of their total production for the respective periods. These results have to be compared with similar data for hand-milked cows kept under conditions as nearly similar as possible to those under which the machine-milked cows were kept.

It is impracticable to include within the space of this bulletin the voluminous records of production of milk and butter fat for the various cows that have accumulated during the progress of these experiments. In order to show the variations in the production of machine-milked cows from week to week, and especially the changes in the amounts of strippings secured from machine-milked cows during a long period, the complete records for the production of three cows are given. (See Appendix, p. 125.) Two of these cows (Dorine and Perchance, both mature) have been selected as representing different types with regard to their attitude toward machine-milking, viz., those that did and those that did not take kindly to this method of milking. The third complete record of production on machine-milking given is for the heifer, Jessie, which was 2½ years old at the beginning of the experiments, and took kindly to machine-milking from the beginning. Jessie was admitted to the Advanced Register of the American Guernsey Cattle Club during the year she was

machine-milked, with a production of 5,589 pounds of milk and 307.34 pounds of butter fat to her credit.

The production of all the cows included on the experiments for the first and the last week of machine-milking, with the amounts of strippings obtained for both weeks will be seen in Table III. This also gives the average weekly decrease in production for the different cows, with their total and average weekly production of milk and butter fat during the period that they were milked by machine.

It will be noted that 29 different cows were included in the experiments; these were machine-milked for periods ranging from 4 to 76 weeks, 11 cows being machine-milked during two different lactation periods. One cow, Double Time, was milked for a continuous period of 62 weeks, and two other cows for 59 and 54 consecutive weeks. The experiments included 40 different trials lasting on the average nearly 26 weeks. The cows on the experiments had been in milk from 3 to 412 days at the beginning of the trials, the average time from calving at that time being 114 days. Some 19 cows were within two months from calving when placed on the experiments, and eight had been milked more than 200 days. We have, therefore, represented in these trials a considerable range as to stage of the lactation periods of the cows, as well as other factors, like age, breed, and live weight of the different cows. It follows from this that the experiments were conducted under greatly varying conditions as to disposition or temperament of the cows, quality of teats and udder, and other factors that would influence the efficiency of the milking machine.

DECREASE IN WEEKLY PRODUCTION. The weekly production of 26 weeks, decreased on the average 2.9 pounds milk and 0.12 pounds fat. The figures for the average weekly decrease in production for cows kept under similar conditions as these, except that they were milked by hand, has been found to be identical with these, viz., on the average, 2.9 pounds of milk and 0.12 pound of fat.[4] There is, therefore, no difference between the results obtained by hand-milking and the average data given in the table for machine-milked cows.

---

[4] Wis. Expt. Sta. Bul. 102, p. 69.

TABLE III.—PRODUCTION OF COWS ON MILKING-MACHINE EXPERIMENTS, 1906–1908.

NAME OF COW.	Days from calving at beginning.	Number of weeks machine milked.	FIRST WEEK. Milk.	FIRST WEEK. Butter fat.	FIRST WEEK. Strippings.	LAST WEEK. Milk.	LAST WEEK. Butter fat.	LAST WEEK. Strippings.	AVERAGE DECREASE PER WEEK. Milk.	AVERAGE DECREASE PER WEEK. Butter fat.	TOTAL PRODUCTION. Milk.	TOTAL PRODUCTION. Butter fat.	AVERAGE WEEKLY PRODUCTION. Milk.	AVERAGE WEEKLY PRODUCTION. Butter fat.
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Laura	188	20	118.4	5.67	7.0	19.1	1.05	1.4	5.2	.24	1,468.6	74.42	73.4	3.72
Do	3	14	169.1	6.56	10.4	155.1	6.79	4.4	1.1	+ .02	2,490.7	108.81	177.9	7.77
Double Time	412	62	156.0	7.61	3.6	35.2	1.92	†	2.0	.09	7,219.6	362.89	116.4	5.85
Perchance	43	30	150.7	6.08	8.7	64.2	3.11	2.8	2.9	.10	2,830.0	123.29	94.3	4.11
Do	18	28	213.4	9.35	5.5	205.0	8.92	4.2	.3	.02	5,620.0	245.87	200.7	8.78
Just in Time	116	41	120.0	6.47	14.5	41.9	2.80	3.6	2.0	.09	3,216.0	175.86	78.4	4.29
Do	49	33	177.2	8.65	1.9	128.8	6.57	1.3	1.5	.07	4,445.6	226.39	134.7	6.86
Jewel	116	26	124.6	7.08	1.9	65.1	4.06	1.3	2.4	.12	2,490.7	150.94	95.8	5.81
Do	18	28	184.1	10.77	5.4	116.2	6.86	1.1	2.5	.14	4,031.1	230.86	143.9	8.24
Broadway	*356	13	42.6	2.49	†	25.1	1.41	†	1.5	.09	510.4	28.82	39.3	2.22
Do	22	33	90.6	4.71	6.2	114.8	6.89	9.6	+ .8	+ .07	3,024.4	180.14	91.6	5.46
Macella	21	33	245.6	12.89	3.9	142.9	8.43	4.6	3.2	.14	6,863.2	396.11	208.0	12.00
Godwin	10	33	129.3	6.59	7.8	142.8	7.71	5.5	+ .4	+ .04	4,314.0	242.53	130.7	7.35
Sadie	134	19	121.6	5.39	2.1	96.7	4.30	1.2	1.4	.06	2,125.9	95.20	111.9	5.01
Dorine	130	54	137.5	7.64	3.8	25.7	1.59	1.1	2.1	.11	4,479.6	248.82	83.0	4.61
Do	13	22	242.0	14.16	5.2	197.6	10.08	3.1	2.1	.19	4,778.4	254.03	217.2	11.55
Floradora	181	40	110.7	6.15	10.8	22.4	1.40	1.5	2.3	.12	2,590.0	147.32	64.8	3.68
Jessie	8	59	168.4	9.01	5.0	64.2	4.09	1.4	1.7	.08	5,955.8	337.04	100.9	5.71
Queen	37	33	198.7	9.84	8.3	153.6	7.68	5.5	1.4	.07	5,272.5	270.19	159.8	8.19
Countess	152	17	144.2	6.63	†	69.0	3.78	†	4.7	.18	1,855.1	93.66	109.1	5.51
Hannah	229	25	123.3	5.96	1.1	80.4	4.18	3.7	1.8	.07	2,599.1	130.18	104.0	5. 1
Cozie	39	4	202.0	11.68	6.7	191.6	10.40	6.3	3.5	.43	776.5	43.58	194.1	10.90
Alma	233	6	120.7	3.96	34.7	27.5	.76	4.2	18.6	.64	425.9	13.88	71.0	2.31
Ormsby	43	26	203.5	5.39	2.1	122.4	3.68	1.5	3.2	.07	4,085.1	116.35	157.1	4.48
Josephine	179	28	183.2	5.99	12.3	87.3	3.17	1.4	3.6	.10	3,719.6	117.28	132.8	4.19
Johanna	328	6	119.3	4.60	8.1	39.6	1.75	1.7	15.9	.57	437.0	17.99	72.8	2.98
Maggie	72	43	268.7	8.68	10.2	19.3	.64	2.5	5.9	.19	7,331.8	230.55	170.5	5.36
Do	15	28	257.3	9.60	6.4	236.9	7.58	3.3	.8	.07	6,706.3	210.91	239.5	7.53
McGeoch	52	19	298.9	9.20	†	177.9	5.92	†	6.7	.18	4,362.3	144.97	229.6	7.63
Maxie	104		282.3	7.14	†	18.2	.71	†	7.8	.19	7,124.0	217.57	203.5	6.22
Do	11		361.5	12.76	12.9	370.5	10.37	9.5	+ .2	.09	9,529.4	279.06	340.3	9.97
Aggie	88	18	172.3	5.69	1.4	177.5	6.12	1.4	+ .3	+ .03	3,041.9	101.44	169.0	5.64
Kate	74	26	222.0	7.61	†	140.5	4.50	10.3	3.3	.12	4,892.8	156.88	188.2	6.03
Christina	39	35	232.1	9.28	3.6	49.8	2.88	7.0	5.4	.19	6,083.3	244.70	173.8	6.85
D	143	19	205.1	8.41	7.3	194.3	7.38	7.1	.6	.06	3,583.5	141.05	188.6	7.43
Priscilla	266	9	99.1	3.72	8.6	57.8	2.46	6.4	5.2	.16	703.3	27.68	78.1	3.08
Do	32	10	233.4	8.64	7.9	246.3	8.62	7.9	+1.4	....	2,575.6	90.90	257.6	9.09
Adelaide	236	9	131.6	5.53	10.9	57.5	2.56	1.9	9.3	.37	903.8	37.81	100.4	4.20
Do	33	10	189.2	7.10	7.3	312.5	10.47	23.4	+13.7	+ .37	2,846.7	100.74	284.7	10.07
Clara	316	14	54.9	2.22	†	41.1	1.58	†	1.0	.05	629.7	24.89	45.0	1.78
Av. of 40 trials	**114**	**25.9**	**175.2**	**7.42**	**7.5**	**113.5**	**4.88**	**4.5**	**2.9**	**.12**	....	....	**145.8**	**6.19**

*Aborted. †Not stripped.

The results, as to the rates of decrease in the weekly production, of individual cows on machine-milking varied greatly, as shown in the preceding table, viz., from a decrease of 18.6 pounds to a gain of 13.7 pounds in production of milk, and from a decrease of 0.64 pound to a gain of 0.37 pound in fat production. The wide variations in the rates of decrease in the weekly production of the different cows are due to several factors, the most important ones being the attitude of the cows to machine-milking, the stage of lactation when the cows were placed on the experiments, and the length of the trials. We note that only two cows, Alma and Johanna, decreased more than 10 pounds milk and 0.5 pound fat per week, while one cow, Adelaide, in the second trial increased in weekly production at the rate of 13.7 pounds milk and 0.37 pound fat.

The trials of the first two cows were of short duration, viz., only four and six weeks, respectively, and were made at an advanced stage of lactation, viz., 233 and 328 days from calving, for Alma and Johanna, respectively. The former cow was naturally a hard milker and did not take kindly to machine-milking; partly for this reason, and partly on account of the conformation of her udder (see Appendix), machine-milking was not a success in her case, as is indicated also by the large amount of strippings obtained from her. Both she and Johanna were near the end of their lactation at the close of the trials. On the other hand, the increase in Adelaide's weekly production during the progress of her second trial was due to the stimulating effect of excellent pastures during early summer toward the end of the trial here considered. The corresponding results for her first trial were lower than the average data for all the cows, so that the average figures for the decrease in production for both trials with this cow do not vary greatly from the average rate of decrease obtained on the whole series.

The variations in the weekly decrease in production obtained with the different machine-milked cows will be further explained by the subsequent discussions in this bulletin and by the notes included in the Appendix as regards the individual cows on the experiments and their attitude toward the milking machine.

AVERAGE WEEKLY PRODUCTION OF COWS. Table III shows that the weekly production for the cows during the periods when they were milked by machine was, on the average, 145.8 pounds

milk and 6.19 pounds fat. The data obtained on hand-milking which furnish the best comparison with these figures are those for the average production of the dairy herd during either earlier years or winter periods which are given in the reports of this station. These figures for the year 1905–06 are especially valuable for this comparison, since all the cows in the herd were milked by hand during this period and were, with but few exceptions, the same as during the time of the milking-machine experiments. The average weekly production of all the cows in the herd (30 cows) for the average number of days they gave milk during this year was 162.4 pounds milk and 6.72 pounds fat, and for the winter period, 160.1 pounds milk and 6.82 pounds fat.

We note, therefore, that the cows averaged somewhat lower in weekly production of milk and butter fat during the periods they were machine-milked than the herd averaged both for the year 1905–6 and the winter period of that year. The machine-milked cows were, on the average, 114 days from freshening at the beginning of the experiments, against 126 and 148 days for the cows included during the year and the winter periods, respectively. This would give the former cows a slight advantage; on the other hand, the production for these cows was somewhat lowered from the fact that the periods considered included the first weeks on machine milking when the cows had not yet become accustomed to this method of milking and did not, therefore, do as well as later on. In view of the many factors that influence the production of cows at a given period, it cannot be stated definitely that the differences observed in the average production of the cows on hand and on machine-milking, were due wholly to the difference in the method of milking practiced, but the data given shows that a satisfactory average production was obtained during the period of machine-milking, even though this was not quite up to the yield which might have been secured by hand-milking under otherwise similar conditions.

It is of interest to note in this connection that four cows averaged more than 10 pounds of butter fat a week during the periods of machine-milking, the highest production being obtained with the Jersey cow Macella, viz., 208.0 pounds milk and 12.00 pounds butter fat, as the average of 33 weeks' continuous

machine-milking, (total production during this period, 6,863.2 pounds milk and 396.11 pounds butter fat). The Guernsey cow, Dorine, ranked second, with an average weekly production of 11.55 pounds butter fat for a period of 22 weeks (total production during this time, 4,778:4 pounds milk and 254.03 pounds butter fat. See Table XX, page 126, for comparative figures for these cows during corresponding periods on hand-milking during earlier years. The production of both these cows on machine-milking was the highest they have ever reached for the length of periods given. The maximum average weekly production for the same number of weeks as on machine-milking, during corresponding periods of earlier years on hand-milking was, for Macella 200.1 pounds milk and 11.63 pounds butter fat, and for Dorine 185.2 pounds milk and 9.93 pounds butter fat (see Appendix).

MACHINE VS. HAND-MILKING FOR THE SAME COWS

A number of cows included on the experiments have been in the University dairy herd for several years and records for earlier lactation periods when they were hand milked are therefore available. In order to have the production of the various cows for different lactation periods comparable, the periods on hand-milking considered have in all cases been taken at the same distance from freshening and extended for the same number of weeks as the period of machine milking for each cow. Comparisons have thus been obtained for 10 different cows (15 different lactation periods) on machine milking and for corresponding periods on hand milking for one to four years for the various cows. Where more than one period was available the results have been averaged and the average given in the table. Table IV shows the results of these calculations for corresponding periods of machine and hand-milking. The last horizontal lines of the two tables show the average results for the 15 trials of machine-milking and corresponding data for the cows when milked by hand. The average weekly decrease in the production of milk and butter fat by the cows has also been calculated in per cent of the average production of the cows during the first week considered in these trials.

TABLE IV.—PRODUCTION OF COWS IN THE UNIVERSITY DAIRY HERD FOR STATED PERIODS WHEN MILKED BY MACHINE, 1906–1908, AND WHEN MILKED BY HAND PRIOR TO 1907.

NAME OF COW.	Number of periods	Number of days from calving.	Number of weeks.	FIRST WEEK.			LAST WEEK.			AVERAGE DECREASE PER WEEK.		TOTAL PRODUCTION.		AVERAGE WEEKLY PRODUCTION.	
				Milk.	Butter fat.	Strippings.	Milk.	Butter fat.	Strippings.	Milk.	Butter fat.	Milk.	Butter fat.	Milk.	Butter fat.
				Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Laura ....*M	1	188	20	118.4	5.67	7.0	19.1	1.05	1.4	5.2	.24	1468.6	74.42	73.4	3.72
Laura ....H	3	187	20	121.0	6.25	....	105.6	5.36	....	.8	.05	2232.6	116.01	111.6	5.80
Laura ....M	1	3	14	169.1	6.56	10.4	155.1	6.79	4.4	1.1	+.02	2490.7	108.81	177.9	7.77
Laura ....H	3	6	14	146.3	6.75	....	156.0	7.76	....	+ .7	+.08	2525.4	126.98	180.4	9.07
Perchance ....M	1	43	30	150.7	6.08	8.7	64.2	3.11	2.8	2.9	.10	2830.0	123.29	94.3	4.11
Perchance ....H	2	42	30	178.0	7.38	....	121.8	5.60	....	1.9	.06	4374.5	197.25	145.8	6.58
Perchance ....M	1	18	28	213.4	9.35	5.5	205.0	8.92	4.2	.3	.02	5620.0	245.87	200.7	8.78
Perchance ....H	1	15	28	198.6	8.34	....	135.0	5.94	....	2.4	.09	4843.1	210.11	173.0	7.5[illegible]
Just in Time ....M	1	116	31	120.0	6.47	14.5	73.5	4.04	2.2	1.6	.08	2584.7	139.33	83.4	4.49
Just in Time ....H	1	115	31	127.8	6.01	....	58.2	3.78	....	2.3	.07	2844.9	149.63	91.8	4.83
Just in Time ....M	1	49	33	177.2	8.65	1.9	128.8	6.57	1.3	1.5	.07	4445.6	226.39	134.7	6.8
Just in Time ....H	1	52	33	142.4	6.12	....	76.9	4.15	....	2.0	.06	3720.9	1[illegible]4.51	112.8	5.59
Broadway ....M	1	22	33	90.6	4.71	6.2	114.8	6.89	9.6	+ .8	+.07	3024.4	180.14	91.6	5.46
Broadway ....H	1	25	33	137.2	8.37	....	103.6	6.24	....	1.1	.07	3764.0	218.47	150.6	8.74
Macella ....M	1	21	33	245.6	12.89	3.9	142.9	8.43	4.6	3.2	.14	6863.2	396.11	208.0	12.00
Macella ....H	3	23	33	209.0	11.08	....	138.3	8.73	....	2.2	.07	5234.6	303.85	158.6	9.36
Dorine ....M	1	130	30	137.5	7.64	3.8	84.1	4.75	4.6	1.8	.10	3094.1	173.83	103.1	5.79
Dorine ....H	4	130	30	143.1	7.38	....	73.0	4.44	....	2.4	.10	3205.3	178.03	106.9	5.93
Dorine ....M	1	13	22	242.0	14.16	5.2	197.6	10.08	3.1	2.1	.19	4778.4	254.03	217.2	11.55
Dorine ....H	4	15	22	204.2	10.99	....	131.7	6.95	....	3.5	.19	3731.6	192.42	169.6	8.75
Queen ....M	1	37	33	198.7	9.84	8.3	153.6	7.68	5.5	1.4	.07	5272.5	270.19	159.8	8.19
Queen ....H	1	35	33	207.4	10.58	....	127.6	6.95	....	2.5	.11	5279.1	260.51	160.0	7.89
Josephine ....M	1	179	28	183.2	5.99	12.3	87.3	3.17	1.4	3.6	.10	3719.6	117.28	132.8	4.19
Josephine ....H	1	179	28	213.7	7.48	....	140.5	5.62	....	2.7	.07	5063.4	171.56	180.8	6.13
Maggie ....M	1	72	43	268.7	8.68	10.2	19.3	.64	2.5	5.9	.19	7331.8	230.55	170.5	5.36
Maggie ....H	1	69	43	314.7	10.07	....	185.2	6.11	....	3.1	.09	10132.9	334.85	235.6	7.79
Maggie ....M	1	15	28	257.3	9.60	6.4	236.9	7.58	3.3	.8	.07	6706.3	210.91	239.5	7.53
Maggie ....H	3	15	28	322.2	12.81	....	228.9	7.46	....	3.5	.20	8135.8	276.33	290.5	9.87
Cozie ....M	1	39	4	202.0	11.68	6.7	191.6	10.40	6.3	3.5	.43	776.5	43.58	194.1	10.90
Cozie ....H	3	40	4	180.3	9.53	....	161.2	8.66	....	6.3	.29	690.0	36.72	172.5	9.18
Average ....M	15	63	27	185.0	8.53	7.4	124.9	6.01	3.8	**2.3**	**.11**	....	....	152.1	7.11
Average ....H	32	63	27	189.7	8.61	....	129.6	6.25	....	**2.4**	**.10**	....	....	162.7	7.53
In per cent of first week's production. Machine-milked										**1.2**	**1.3**				
In per cent. of first week's production. Hand-milked										**1.3**	**1.2**				

* M=Machine-milked. H=Hand-milked.

The figures for the decrease in weekly production and the average weekly production of milk and butter fat are especially important in showing the effect of the two methods of milking on the milk secretion of the cows. We note that considerable variations occurred in the decrease in weekly production, as well as in the average weekly production of the various cows, owing to differences in the individuality of the cows and in the stage of the lactation when the trials commenced. In the case of the machine-milked cows there was a range from an average weekly gain of 0.8 pound milk and 0.07 pound butter fat (Broadway, for a period of 33 weeks) to a weekly decrease of 5.9 pounds milk and 0.19 pound butter fat (Maggie, for a period of 43 weeks), the average decrease in weekly production for all the cows for the periods considered being 2.3 pounds milk and 0.11 pound butter fat.

The corresponding figures for the same cows during earlier lactation periods on hand-milking were 2.4 pounds milk and 0.10 pound butter fat; or a range from a gain in weekly production of 0.7 of a pound of milk and 0.08 pound of butter fat for Laura (second trial, 14 weeks), to a decrease in weekly production of 6.3 pounds milk and 0.29 pound butter fat for Cozie (40 weeks' trial). Calculated in percent of the average production of the cows during the first week of the trial, the figures obtained for weekly decrease in production are: on machine milking, 1.2 per cent for milk and 1.3 per cent for butter fat, and for hand milking, 1.3 per cent for milk and 1.2 per cent for fat. These results agree so closely that they may be considered identical for all practical purposes.

The average weekly production of the cows during the machine-milking trials was 152.1 pounds of milk and 7.11 pounds of butter fat, and that of the cows during corresponding earlier lactation periods on hand-milking, 162.7 pounds of milk and 7.53 pounds of butter-fat. The only factor influencing the production of the cows during these periods, that might be of importance in this connection, besides the method of milking practiced, was the age of the cows. Since the milking-machine trials in all cases followed the periods of hand-milking, the former would have an advantage in the case of young cows and heifers, whose production would naturally be improved by age, while they would be at a disadvantage in the case of old cows.

The average age of the 10 cows whose records are considered in the tables was 7.9 years at the middle of the milking-machine trials; three of the cows were 10 years old, or over, and only two five years of age or below. The average production of the lot of 10 cows might, therefore, be expected to be somewhat lower during the period of machine-milking than during the preceding periods of hand milking.

Two of the old cows had a greater weekly decrease in production of milk and butter fat on machine than on hand-milking, and the average production per week for all three old cows (five trials) was in all cases lower during machine-milking than during the corresponding portions of early lactation periods when they were milked by hand. Considering the data for all the cows given in the table we note that there was a larger rate of decrease in the production of milk during the former periods in the case of six trials and a lower rate in the case of nine trials, while the decrease in the production of butter fat was higher in nine trials and lower in four trials, there being no difference in the rate of decrease in two trials. When the average weekly production of the cows is considered we find a lower production of milk on machine-milking than on hand-milking in 10 trials and a higher production in five trials. The production of butter fat was lower in nine trials and higher in six trials on machine-milking than on corresponding periods of hand-milking.

It is not likely that the differences observed in the production of the cows during the periods of machine and hand-milking are due wholly to an actual decrease in the productive capacity of the cows through their advancement in age, but this has doubtless been a factor in determining the results. The difference in the method of milking the cows was, in all probability, also of some importance in this connection, as suggested by the fact that a somewhat lower average weekly production of milk and butter fat was obtained on the machine-milking trials than in the case of hand-milking for our entire herd during the preceding year or winter period.

RATE OF DECREASE IN PRODUCTION OF MACHINE AND HAND-MILKED COWS

It seemed desirable to obtain comparative data for the University herd as to the manner in which the cows milked by machine and those milked by hand maintained their production during an extended period of time. All available data for two 6-month periods, viz., January 1 to June 30, 1907 and 1908, were accordingly compared, and the summaries of the figures are given here, with records for 1907 for six and seven machine and hand-milked cows, respectively, and for 1908 for 10 machine-milked and four hand-milked cows.

The reason why these particular 6-month periods were chosen for comparison of the effect of continuous machine and hand-milking was the following: A compilation of the results for the first six months of this investigation led to a study of the records of the cows after they were turned to pasture in the spring of 1907, and it was found that the cows which had been machine-milked during the preceding period did not keep up as well in their production during the pasture period as did the hand-milked cows. They made a larger increase in production during the first week on pasture than the hand-milked cows in the herd that were compared with them, and decreased appreciably in production during the following month, while the hand-milked cows continued to increase in production during this time.

It was feared that this unfavorable showing might be a characteristic effect of machine milking on the milk secretion, and it was therefore decided to delay the publication of the results of the investigation until a duplicate trial could be made during the following pasture season. During the latter period no characteristic differences were to be observed in the production of hand and machine-milked cows, as will be noted by a study of the data presented below. Tables V–VI give summary figures of the production of milk and butter fat and the average per cent of fat in the milk for each week of the 6-month periods of the two years. In Table VI the yields have been calculated on a percentage basis, those of the first week being placed at 100.

TABLE V.—AVERAGE WEEKLY PRODUCTION OF MILK AND BUTTER FAT BY MACHINE-MILKED AND BY HAND-MILKED COWS JANUARY — JUNE, 1907 AND 1908.

NUMBER OF WEEK.	1907.						1908.					
	Average for six machine-milked cows.*			Average for seven hand-milked cows.*			Average for ten machine-milked cows †			Average for four hand-milked cows.†		
	Milk.	Butter fat.		Milk.	Butter fat.		Milk.	Butter fat.		Milk.	Butter fat.	
	Lbs.	Per cent.	Lbs.	Lbs.	Per cent.	Lbs.	Lbs.	Per cent.	Lbs.	Lbs.	Per cent.	Lbs.
1st	140.6	4.72	6.63	127.5	5.25	6.69	183.3	4.70	8.62	161.1	4.25	6.81
2d	141.9	4.48	6.35	123.9	5.24	6.63	181.3	4.61	8.35	157.8	4.32	6.81
3d	135.2	4.30	5.81	119.3	5.18	6.18	182.9	4.41	8.06	156.9	4.25	6.67
4th	130.9	4.50	5.89	118.2	5.31	6.28	181.7	4.41	8.01	148.9	4.15	6.18
5th	125.1	4.56	5.70	112.6	5.31	5.98	178.3	4.50	8.03	142.2	4.45	6.36
6th	127.2	4.43	5.64	113.9	5.18	5.90	175.5	4.47	7.85	147.5	4.30	6.34
7th	130.9	4.35	5.69	115.2	5.14	5.92	171.5	4.40	7.55	143.1	4.33	6.20
8th	125.5	4.36	5.47	111.7	5.06	5.65	172.9	4.47	7.73	145.4	4.39	6.39
9th	121.9	4.34	5.29	105.7	5.15	5.44	168.3	4.56	7.67	141.5	4.42	6.25
10th	122.5	4.20	5.15	105.1	5.12	5.38	167.2	4.56	7.62	141.3	4.42	6.24
11th	125.7	4.29	5.39	110.1	5.08	5.59	160.8	4.47	7.18	140.6	4.38	6.15
12th	122.9	4.22	5.19	111.0	4.99	5.54	157.5	4.56	7.18	137.4	4.37	6.06
13th	122.0	4.14	5.05	112.4	5.03	5.65	157.4	4.59	7.21	134.1	4.49	6.02
14th	123.9	4.33	5.36	114.3	5.14	5.87	159.2	4.54	7.22	136.5	4.42	6.03
15th	118.8	4.26	5.06	112.3	5.18	5.82	159.2	4.51	7.18	137.3	4.46	6.12
16th	115.6	4.20	4.85	108.8	5.26	5.72	149.5	4.57	6.83	130.0	4.48	5.82
17th	109.9	4.30	4.82	105.4	5.35	5.64	153.4	4.49	6.88	129.4	4.40	5.70
18th	113.5	4.30	4.88	105.5	5.31	5.65	152.2	4.60	7.00	129.5	4.49	5.82
19th	119.4	4.31	5.15	112.2	5.32	5.97	153.9	4.64	7.14	132.0	4.55	6.00
20th	117.1	4.49	5.26	110.1	5.56	6.12	156.5	4.70	7.36	133.0	4.67	6.21
21st	121.3	4.60	5.58	119.7	5.76	6.90	175.3	4.82	8.45	149.8	4.99	7.47
22d	116.6	4.31	5.02	122.3	5.35	6.54	181.2	4.71	8.54	164.0	5.22	8.56
23d	112.8	4.47	5.04	131.2	5.27	6.91	180.4	4.58	8.26	162.8	4.87	7.94
24th	111.5	4.39	4.90	136.3	5.23	7.13	185.6	4.54	8.42	163.9	4.87	7.99
25th	111.6	4.33	4.83	132.9	5.17	6.87	178.2	4.49	8.00	155.4	4.76	7.41
26th	114.5	4.35	4.98	132.3	5.05	6.68	171.0	4.31	7.41	145.7	4.88	7.12

* Average time from last calving, Jan. 2, '07: for machine-milked cows, 191 days; for hand-milked cows, 193 days. Due to calve in number of days from July 2, '07, for machine-milked cows, 148 days (one cow not bred): for hand-milked cows, 135 days.

† Average time from last calving, Jan. 1, '08: for machine-milked cows, 75 days; for hand-milked cows, 183 days. Due to calve in number of days from June 30, '08, for machine-milked cows, 116 days; for hand-milked cows, 98 days (two cows not bred). Data for only 3 cows included for hand milking during last five weeks.

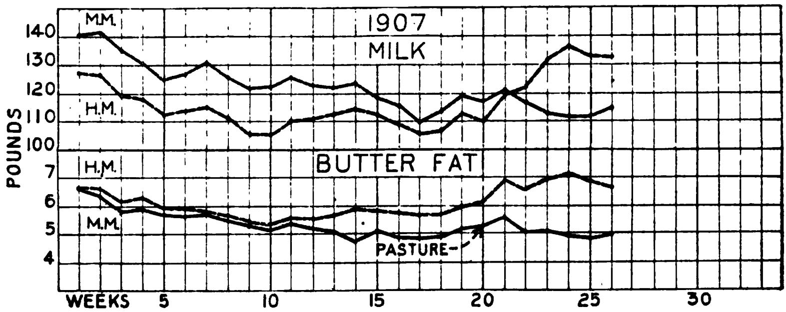


Figure 5.—Diagram of weekly yields of milk and butter fat from hand-milked (H. M.) and machine-milked (M. M.) cows during the period January-July, 1907.

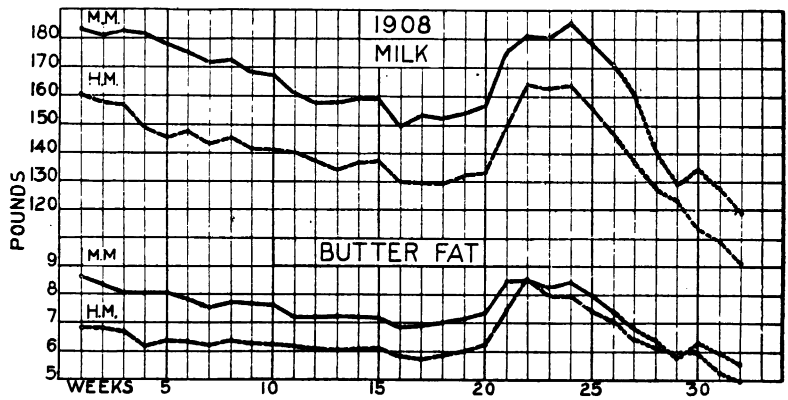


Figure 6.—Diagram showing weekly yields of milk and butter fat from hand-milked (H. M.) and machine-milked (M. M.) cows during the period January-July, 1908. The dotted lines at the right show the production of the cows after the experiments were concluded.

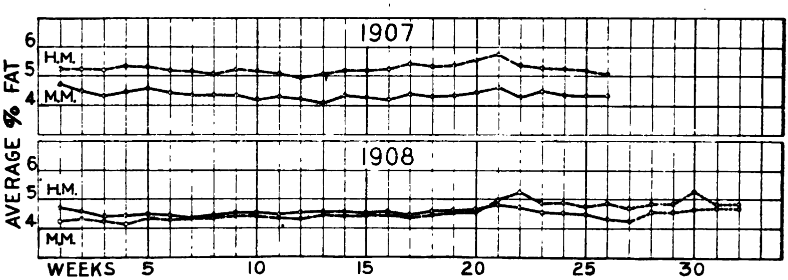


Figure 7.—Diagram showing average per cent of butter fat in milk from hand-milked (H. M.) and machine-milked (M. M.) cows during the period covered by the experiments in the seasons of 1907 and 1908.

It will be noted that the six machine-milked cows in 1907 decreased in their weekly production of milk from 140.6 to 114.5 pounds, and in production of fat from 6.63 to 4.98 pounds between January 2 and July 2. The seven hand-milked cows, on the other hand, increased in production during the same period from 127.5 to 132.3 pounds milk, there being practically no change in the fat produced at the extremes of this period. Figured on a percentage basis of the production during the first week, the machine-milked cows decreased 18.4 per cent. in milk and 24.9 per cent in fat, while the hand-milked cows increased on the average 2 per cent. in milk and decreased 0.1 per cent in fat.

TABLE VI.—COMPARISON OF MACHINE-MILKED WITH HAND-MILKED COWS JANUARY–JUNE, 1907 AND 1908 (IN PER CENT OF FIRST WEEK'S PRODUCTION.)

Number of week.	1907.				1908.			
	Milk.		*Butter fat.*		*Milk.*		*Butter fat.*	
	Machine.	Hand.	Machine.	Hand.	Machine.	Hand.	Machine.	Hand.
1st	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2d	101.0	99.2	95.9	99.1	98.9	98.8	96.9	100.0
3d	95.8	93.0	87.6	92.4	100.0	98.1	93.5	97.9
4th	93.0	92.2	88.8	93.9	99.5	93.1	92.9	90.8
5th	88.7	88.3	86.0	89.4	97.2	91.3	93.2	93.4
6th	90.1	89.1	85.1	88.2	96.2	92.5	91.1	93.1
7th	93.0	89.8	85.8	88.5	94.0	89.4	87.6	91.0
8th	89.4	87.5	82.5	84.5	94.5	90.6	89.7	93.8
9th	86.5	82.8	79.5	81.3	91.8	88.7	89.0	91.8
10th	87.2	82.0	77.7	80.4	9[illegible].3	88.1	88.4	91.6
11th	89.4	85.9	81.3	83.6	88.0	88.1	83.3	90 4
12th	87.2	86.7	78.3	82.8	86.3	85.6	83.3	89.0
13th	86.5	87.5	76.2	84.5	85.8	83.7	83.6	88.4
14th	87.9	89.1	80.8	87.7	86.9	85.6	83.8	88.5
15th	84.4	87.5	76.3	8[illegible].0	86.9	85.6	83.3	89.9
16th	82.3	85.2	73.2	85.5	82.0	81.6	79.2	85.5
17th	78.0	82.0	72.7	84.3	83.6	80.6	79.8	83.7
18th	80.9	83.6	73.6	84.5	83.1	81.3	81.2	85.5
19th	84.4	87.5	77.7	89.2	84.2	82.5	82.8	88.1
20th	83.0	86.0	79.3	91.5	85.8	83.1	85.4	91.2
21st	85.8	93.8	84.2	103.0	95.6	93.8	98.0	110.0
22d	83.0	94.6	75.7	97.8	99.0	102.0	99.1	126.0
23d	80.0	102.0	76.0	103.0	98.4	102.0	95.8	117.0
24th	79.4	106.0	73.9	107.0	102.0	103.0	97.7	117.0
25th	79.4	103.0	72.9	103.0	97.3	97.1	92.8	109.0
26th	81.6	102.0	75.1	99.9	93.4	91.7	86.0	105.0

In 1908 the 10 machine-milked cows decreased in weekly milk production from 183.3 to 171.0 pounds between January 1 and June 30, and in fat production from 8.62 to 7.41 pounds. At the same time the four hand-milked cows decreased in milk during this period from 160.1 to 146.7 pounds and increased in fat from 6.81 to 7.12 pounds (averages for three cows only con-

sidered at the end of the period). Expressed in percentage figures we have that the machine-milked cows lost 6.6 per cent. of milk and 14 per cent. of fat during the period considered, against a loss of 8.3 per cent. in milk and a gain of 5.0 per cent. in fat for the hand-milked cows. If the data for all four hand-milked cows are averaged, the yields during the 26th week were, 125 pounds milk and 6.11 pounds fat, showing a loss of 21.9 per cent. in milk and 10.3 per cent in fat during the six months considered.

The explanation offered by the manufacturers for the unfavorable results obtained with the machine-milked cows during the pasture season of 1907 was that a too high vacuum had been used in our herd during the preceding three or four months, viz., 16½ to 17 inches, which latter figure the instructions furnished with the machine gave as the maximum vacuum to be used in operating the same. The importance of keeping the vacuum lower than originally directed was evidently brought out by practical experience with the machine at about the time of our first pasture period, and in accordance with the suggestion of the manufacturers the vacuum for operating the milking machine has been uniformly maintained at 15 to 15½ inches since the summer of 1907. In view of the favorable results for machine milking obtained since this time and especially during the pasture season, we believe that the manufacturers' explanation of our results of the seasons of 1907 is correct. In order to avoid any injurious influence on the milk-secreting power of the cows, it is evidently of vital importance not to maintain a higher vacuum than 16 inches at a maximum, and, in case of a mixed herd, to maintain as uniform a vacuum of 15½ inches as possible.

EFFICIENCY OF MACHINE MILKING

The question of the thoroughness of the milking will in the end determine the practicability of a milking-machine. With but few exceptions, the cows placed on the milking machine in the dairy herd took kindly to this method of milking after they had become accustomed to it, without regard to the breed or the age of the cows. The only cows that gave any difficulty whatever were Clara, McGeoch and Alma. The following cows did

not take kindly to machine-milking at the beginning of the trials: Josephine, Just in Time, Maggie, Perchance, Priscilla and Queen, but all gradually became accustomed to this method of milking, and later on did not give any trouble. The chief difficulty with Clara was apparently pure obstinacy and, to a certain extent, this was true also of McGeoch and Perchance. These three cows seemed to object to being milked from the left, from which side it happened they were machine-milked. Perchance was induced to give down her milk readily by feeding her the grain ration just prior to milking; McGeoch submitted after about three weeks' time had elapsed, but Clara evidently disliked the machine during the greater part of the time she was machine-milked. The more nervous cows of the herd were at first more or less annoyed by the noise of the machine, but after a few days paid very little attention to it.

As a general rule, the cows did not quite come up to their usual yields the first few days they were placed on the machine, but, as we have seen, the yields obtained during the first few weeks were nearly up to normal (see p. 70). In the case of several cows the yields of milk obtained by machine milking were normal from the beginning, and other cows apparently milked better and quicker by machine than by hand after they were once used to the former method of milking.

On the other hand, the shape, size, and quality of the udders and teats of a few cows, notably Alma and Christina, seemed to make it impossible for the machine to do efficient work. In the case of the former cow her teats were not only warty and meaty, but rather short and blunt and not well attached to the udder, while the teats of the latter cow were quite short and very small. Teats abnormally small or large are, according to our experience, apt to render machine-milking more or less unsatisfactory. Teats which are very close together, as in the case of Floradora, also give some difficulty.

The quality of the udder as regards fleshiness and evenness of quarters apparently influences the efficiency and the ease with which the milk is drawn by the machine. The cows, Josephine, Ormsby, Dorine, Just in Time, and Double Time, all of which possessed normal udders, gave down their milk with very little manipulation, while in the case of other cows considerable manipulation was necessary, owing to their udders or teats being more or less defective. The amount of strippings

obtained during the progress of the experiment for the different cows gradually decreased from the first to the tenth week, and after this period the weight of strippings remained practically constant, at one to three pounds per week, or 0.1 to 0.2 of a

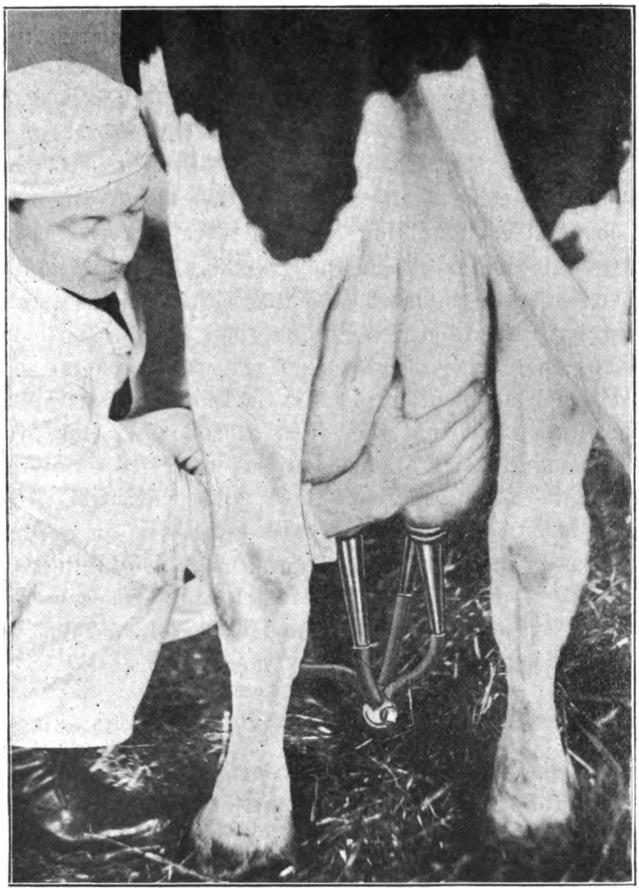


Figure 8.—Manipulations of udder before teat cups are removed. This was often necessary in order to secure as much milk as possible from the cow. The last of the milk in the udder was obtained by stripping after the teat cups and mouth pieces were removed.

pound per milking, the average weight of strippings from different cows when they had become accustomed to machine milking being a little over two pounds per week, or about two ounces per milking. Since strippings are from two to three times richer in butter fat than the main portion of a milking (see page 91),

this is equivalent to about one-half pound of ordinary milk per cow for each milking. Judging from the data obtained with our herd, the amount of fat in the strippings should not exceed 5 per cent, and may in many cases be reduced to below 2 per cent of the total amount of fat produced by the cows.

It is a somewhat unsettled question as to what effect not stripping the cows after machine-milking will have on the milk secretion both during the balance of the lactation period considered, and during subsequent lactation periods. Dairymen generally believe that the effect will be injurious, causing cows to dry up sooner than will be the case with cows carefully milked clean at each milking. While there is good reason for holding to this belief, it must be granted that no direct proof for its correctness is at hand, and it is a fact that a number of dairymen have abandoned stripping their cows after machine-milking, as they have decided that the extra amount of milk obtained is not sufficient to pay for the trouble of stripping the cows each time, and that the effect of following this practice, on the permanent dairy qualities of the cows, is not of sufficient importance to be considered. Cows, like Christina, Adelaide and Alma in our herd, which persist in leaving an appreciable amount of milk in the udder after the machine-milking is done, giving 0.5 of a pound or more of strippings at each milking, must, however, doubtless be stripped by hand, or must be disposed of if the milking is done by machinery.

COMPARISON OF THOROUGHNESS OF MACHINE AND HAND MILKING

In order to obtain some definite information as to the comparative thoroughness of machine and hand-milking, under the conditions present in the University dairy herd, the following trial was conducted.

During the week of November 21 to 27, 1906, it was arranged to have a control lot of 10 cows stripped by the manipulation method[5] by Mr. Harris, Assistant in Dairy Tests, immediately after the regular milkers had finished. In Table VII these results are compared with the strippings for 10 machine-milked cows for the tenth week after they had been put on the milking machine, at which time they had become accustomed to machine-milking.

---

[5] Wis. Expt. Sta. Bul. 96.

It will be seen from the last lines of the table that the strippings secured from both lots of cows were practically the same in amount or in per cent of the total milk yield, for the weeks considered, the average amounts of strippings from the 10 machine-milked cows for the week being 21.6 pounds (1.7 per cent of the total milk yield), and for the 10 hand-milked cows, 21.9 pounds (1.6 per cent of the total yield). The milking in our dairy herd is done by young men who are especially interested in dairy cattle and are fully aware of the importance of thorough milking; hence they are likely to exercise more than ordinary care in doing this work.

TABLE VII.—STRIPPINGS OBTAINED PER WEEK FROM MACHINE-MILKED AND HAND-MILKED COWS.

NAME OF COW.	MACHINE MILKED COWS.*			NAME OF COW.	HAND-MILKED COWS.†		
	Total milk.	Strippings.			Total milk.	Strippings.	
	Lbs.	Lbs.	Per cent of total.		Lbs.	Lbs.	Per cent of total.
Laura	74.9	3.9	5.2	Brownie	110.1	2.4	2.2
Perchance	108.9	2.8	2.6	Queen	120.8	1.5	1.2
Just in Time	83.4	1.3	1.5	Macella	187.4	3.0	1.6
Double Time	119.0	1.1	.9	Sadie	109.0	.9	.8
Floradora	79.7	2.9	3.6	Muriel	120.3	.8	.7
Dorine	109.9	1.5	1.4	Cozie	102.2	3.2	3.1
Josephine	137.9	1.4	1.0	Joe	152.6	2.5	1.6
Ormsby	163.6	1.3	.8	Maggie	290.3	4.1	1.4
Maggie	205.5	2.1	1.0	Artis	107.1	1.9	1.8
Christina	187.9	3.3	1.8	Marie	66.3	1.6	2.4
Total	1,275.7	21.6	....		1,365.5	21.9	....
In per cent	....	**1.7**	....		....	**1.6**	....

*Yields during tenth week from beginning of machine milking.
†Nov. 21-17, 1906.

The thoroughness of the work of hand milking in 13 different dairy herds of the state was studied by one of the writers (Woll), and the investigation reported in a bulletin[5] of this Station. The results there given show that by the use of the manipulation method of milking after the cows were milked in the ordinary manner by the regular milkers, an amount of after-milk or strippings was obtained ranging in the different herds between 0.55 and 1.87 pounds per day per cow, or 1.08 pounds on the average, per cow, for all the herds. This is equivalent to

over $7\frac{1}{2}$ pounds of strippings per week, or more than three times as much as was obtained on the average from the 10 machine-milked cows; six out of the 10 cows that were stripped by hand after machine milking gave less than one-third of the amount of strippings stated, and not one of these cows gave as much milk in the strippings as the average for the cows in the 13 herds above mentioned. The conclusion would, therefore, seem justified from these data that the efficiency of the machine milking after the cows have become accustomed to it is practically equal to that of good hand milking, and is doubtless superior to that done on many dairy or other farms.

AMOUNT OF BUTTER FAT IN THE STRIPPINGS

Samples of the strippings from the machine-milked cows were collected and their fat contents carefully determined four times during the investigation, viz., during the first week of the experiment, October 31 to November 9, 1906; April 24 to 30, 1907; April 29 to May 5, and June 17 to 23, 1908. The first two sets of determinations were made for the purpose of ascertaining whether or not there is any tendency for machine-milked cows to leave more and more fat to be stripped out by hand as the period of lactation advanced. The last two sets of determinations were made in order to obtain data as to whether there is any similar tendency under pasture conditions compared with stable feeding. Data for seven cows were available for the first, and for 16 cows for the second comparison. The details as to yields of total milk and strippings for the various cows, the fat contents of both milk and strippings, and the per cent of the total butter fat obtained in the strippings for the various cows are shown in Table VIII.

There was a decrease in the amount of strippings secured and of the fat obtained in the strippings in every case but one in the first set of determinations. The strippings, on the average, amounted to 5.3 per cent of the total milk secretion at the beginning of the trial, November, 1906, and 1.9 per cent six months later. The percentage amount of fat in the strippings figured on the total fat in the milk amounted to 11.0 per cent at the beginning and 3.6 per cent at the end of the trial when the cows had become accustomed to being machine-milked.

TABLE VIII AMOUNT OF FAT IN STRIPPINGS.

Name of cow.	Milk. lbs.	Strippings. lbs.	Per ct. fat: Milk.	Per ct. fat: Strippings.	Per cent of total fat in strippings.	Milk. lbs.	Strippings. lbs.	Per ct. fat: Milk.	Per ct. fat: Strippings.	Per cent of total fat in strippings.
	Oct. 31—Nov. 6, 1906.					*April 24—30, 1907.*				
Double Time...	156.0	3.6	4.88	7.72	3.7	116.8	1.5	4.97	7.90	2.1
Perchance......	150.7	8.7	4.03	5.37	7.7	60.4	2.8	4.50	5.66	5.8
Just in Time...	120.0	14.5	5.39	8.98	20.1	64.2	1.4	5.73	10.40	4.0
Dorine	137.5	3.8	5.56	6.16	3.1	83.4	1.4	5.53	7.08	2.2
Floradora.......	110.7	10.8	5.55	8.97	15.8	49.1	1.4	6.10	9.00	4.2
Ormsby.........	203.5	2.1	2.65	8.76	3.4	122.4	1.5	3.00	9.85	4.0
Josephine.......	183.2	12.3	3.27	11.38	23.4	90.0	1.2	3.48	7.93	3.0
Averages...	**151.7**	**8.0**	......	......	**11.0**	**83.8**	**1.6**	......	......	**3.6**
	April 29—May 5, 1908.					*June 17—23, 1908.*				
Perchance......	185.3	3.6	4.28	8.20	3.8	212.9	4.4	4.29	8.60	4.2
Just in Time...	107.7	1.6	5.30	9.00	2.5	129.2	1.3	5.08	8.50	1.7
Dorine..........	198.1	2.8	5.27	9.80	2.6	208.8	3.6	5.03	9.80	3.3
Maggie..........	215.8	3.3	3.92	7.40	3.8	245.0	3.8	2.99	8.30	4.4
Christina........	172.4	8.2	3.85	6.80	8.4	205.4	7.6	3.69	8.70	8.
Jewel............	126.7	1.7	5.85	16.25	3.8	125.6	1.4	5.74	13.50	2.6
Jessie...........	71.3	2.6	6.10	14.25	8.5	76.2	1.1	5.93	15.00	3.8
Sadie............	107.3	2.1	4.59	14.25	6.9	103.1	.6	4.38	10.50	1.3
Macella.........	184.6	5.6	6.06	14.75	7.4	183.1	4.9	5.83	12.50	5.7
Broadway	85.8	3.3	6.04	10.50	6.8	121.2	10.3	6.12	12.25	17.0
Queen...........	138.4	3.3	5.03	14.50	6.9	165.2	4.9	4.94	16.00	9.6
Goodwin.........	99.6	4.8	6.19	10.00	7.8	148.0	5.7	5.51	9.50	6.6
Adelaide........	230.6	7.7	3.66	12.50	11.4	326.7	26.5	3.44	10.70	25.2
Priscilla	231.9	7.6	3.76	10.00	8.7	269.3	11.1	3.44	11.50	13.8
Aggie	159.1	2.6	3.37	10.25	5.0	176.1	1.3	3.40	9.90	2.2
Maxie...........	307.2	7.6	2.87	5.80	5.0	375.7	8.8	2.89	6.70	5.4
Averages....	**163.9**	**4.3**	......	......	**6.2**	**192.0**	**5.5**	......	......	**7.2**

Comparing the data for stable feeding and pasture conditions at one and a half months later, we find, as the average for 16 cows, that the strippings amounted to 2.6 per cent of the milk secretion during the former and 2.9 per cent during the latter period, an increase of 0.3 per cent; while 6.2 per cent of the total fat was obtained in the strippings in the former case, against 7.2 per cent in the latter. A comparison of the separate figures given in the table for per cent of fat in the strippings shows that nine cows gave higher figures on pasture than on stable feeding and seven gave lower. The slight increase in the figures for pasture are, however, mainly the result of the increase in the amount of strippings and in the proportion of fat obtained in the strippings in the case of two cows, Broadway and Adelaide, since only small differences one way or the other occurred in the case of other cows.

While the results are not conclusive they indicate that the milking machine will give no special difficulties under pasture

conditions in the case of most cows. It may be necessary in some cases to readjust the teat cups and mouth pieces after the cows have been turned to pasture, since the teats of cows often get tender and smaller at this time; the matter of adjustment of teat cups should, therefore, receive careful attention during this period. When this is done, the efficiency of the milking-machine does not, as a rule, appear to be affected by the change from stable to pasture conditions. Teat cups also have to be changed with some cows as the lactation advances and the teats decrease in size. The matter of adjustment of teat cups and mouth pieces to the teats of different cows in the herd, is, in our opinion, the weak point in the B. L. K. milking machine and one that is likely to give considerable trouble in large mixed herds and more or less trouble in herds of any size.

MACHINE-MILKING WITHOUT STRIPPING. The conclusion stated on page 90 with regard to the efficiency of machine-milking naturally raises the question why machine-milked cows should be stripped at all. To obtain some data as to the apparent effect of machine-milking without subsequent stripping on the milk secretion of the cows, a trial was commenced in February, 1907, in which four cows were milked by machine without stripping. Two of the cows placed on this trial, Maxie and McGeoch, were fresh milch cows, while the other two, Broadway and Clara, were far advanced in lactation at the beginning of the trial, and within three months of drying off at that time. The effect of the method of milking practiced may be studied by the gradual decrease in production per week during the progress of the trial as shown in Table IX.

TABLE IX.—DECREASE IN YIELD OF MILK AND BUTTERFAT DURING TWELVE WEEKS.

	Days in milk.	First week.			Twelfth week.		
		Milk.	Fat.		Milk.	Fat.	
		Lbs.	Lbs.	Per ct.	Lbs.	Lbs.	Per ct.
Broadway	354	42.6	2.49	5.85	25.3	1.47	5.80
Clara	316	54.7	2.22	4.05	36.4	1.46	4.00
Maxie	95	282.3	7.14	2.53	272.7	8.59	2.68
McGeoch	52	298.9	9.20	3.08	220.6	7.28	3.30
Total	....	678.5	21.05	....	555.0	18.80	....
Average per cow	**204**	**169.6**	**5.26**	**3.10**	**138.8**	**4.70**	**3.39**
Decrease per week	....	....	....	....	2.8	.05	....
Per ct. decrease weekly	....	....	....	....	1.7	1.0	....

The average weekly decrease in the production of the four cows during the 12 weeks of the trial was 1.7 per cent in milk yield and 1 per cent in production of fat. The average percentage of decrease for milk is slightly higher than that of the 10 cows for an average of about 27 weeks, while the decrease in butter fat production comes a little lower, owing to the low production of one of the cows (Maxie) during the first week of the machine milking, and her high production during the last week, which was her first week on pasture.

The above data have been obtained with only a few cows and the period considered is, moreover, too short to warrant general conclusions to be drawn as to the necessity of stripping machine-milked cows. It would not have been difficult to obtain further data on this point with these or other cows in our herd, but we are strongly of the opinion that the practice of not stripping is unsafe and not to be recommended, at least in the case of breeding herds, even if no absolutely detrimental results have been established by actual experiments, and we have, therefore, been unwilling to take any chances of injuring the future usefulness of cows in our herd by continuing work along this line.

RELATION TO GARGET. Three cases of garget occurred in the herd during the week, April 2 to 9 of this last trial, which in the case of two cows, McGeoch and Clara, might appear to be the result of machine milking without stripping. The third cow, a Brown Swiss, had never been machine-milked, however, which would make it seem that some factor other than the method of milking may be responsible for the trouble, either the feed, the change of weather, or some other common cause. McGeoch has always been subject to attacks of garget, but in the case of Clara, it is possible that the attack came as a result of her not giving down her milk completely to the machine, which, as referred to before, she continually refused to do. While no definite conclusions can be drawn from our limited experience in this respect, it may be that machine milking not followed by stripping will have an injurious effect on cows that do not give down their milk readily. In herds where machine-milking is adopted such cows must either be hand-milked or carefully stripped after being machine-milked until the milk secretion is again perfectly normal. A few other scattered cases of garget occurred in the herd during the progress of the

milking experiments, but it cannot be stated with any degree of certainty that the disease was brought about by the method of milking practiced, since some hand-milked cows also had attacks of garget during this time, as well as the machine-milked cows.

ECONOMY OF MACHINE MILKING

The economical side of the question of machine-milking appeals to the practical dairyman, i. e., whether or not cows can be milked cheaper by this method than by hand; the following discussion of various points relating to this question is based on our experience with the milking-machine in trials with cows in the University dairy herd.

TIME REQUIRED FOR MACHINE MILKING. The time required for machine-milking the cows in the herd was ordinarily much greater than would be required on practical dairy farms, owing to the weighing and sampling of the milk, keeping time, the construction of the cow stalls, etc. During one week of the trial (April 3 to April 10), special arrangements were made, however, so that the attendant had no work to do but to operate the machine as it would be done on ordinary dairy farms.

Twelve cows, giving on the average 14.1 pounds of milk per day, were milked in pairs by the use of two machines. Six different outfits of teat-cups and mouth-pieces were necessary for these cows, owing to the differences in the shape and size of the teats of the cows of various breeds. All the cows were carefully stripped by the attendant immediately after being machine-milked. The time required for machine-milking these 12 cows during the week ranged from 31 to 40 minutes. The average time per cow per milking during the week was slightly less than 3 minutes. The gain in time of machine milking over hand milking comes only from the fact that one man can operate two or three machines and can milk four or six cows in the time ordinarily required to hand-milk one. It appears to be practicable for one man to operate three machines and thus milk six cows at a time (see page 128), but it cannot be expected that one man can operate more than two machines if the milk of each cow is to be kept and weighed by itself and the weight recorded.

CLEANING THE MACHINES. Considerable washing and cleaning must be done where milking machines are used, since teat-

cups, mouth-pieces and rubber connections have to be rinsed with scalding hot water directly before the milking begins and scrupulously cleaned after each milking (see Figure 4); the renewal of absorbent cotton in the relief filters of the pails and

Figure 4.—Method of cleaning connections before and after using the milking machine. The milk pail is connected with the vacuum cock, A, and the water in the pail, E, is run through the teat cups and mouth pieces of the machine to cleanse them. The spouts, B, are the openings from which the milk is poured from the two compartments of the pail. The pail D is fully connected up and C is without connections.

teat-cups also requires extra time. In our work at the dairy barn it has generally taken the attendant at each milking 10 to 20 minutes to get two machines ready for the milking, and 20 minutes to clean them afterwards. This work would be but slightly increased if a larger number of cows were milked by the machine.

COST OF THE MACHINE. The installation of the milking-machine in a herd of, say 30 cows, will involve an expenditure of at least $500, if the cost of an engine or other power required for running the machine is included, viz.,

3 milk pails (milkers) at $75	$225.00
Vacuum pump	75.00
Steel vacuum tank	12.00
Vacuum safety valve	3.50
15 stanchion cocks, at 75c	11.25
2 5-inch vacuum gauges at $2.50	5.00
Total	$331.75

There will, in addition, be the expense of piping and installing the machine which will not be likely to come much below $50, on the average. With a good 2 horsepower engine, worth at least $120, this will bring the total initial cost of inaugurating machine-milking up to about $500. This is a large sum of money to most dairy farmers, and many of them will hesitate to spend this amount for a milking machine, especially so long as they can have no *absolute* certainty that the machine will prove a success under their conditions and will render it unnecessary to continue milking by hand in their herds in the future. To the interest of $500, or say $25 a year, should be added the cost of operating the machine, expenses for repairs, depreciation of machine, etc., and this sum should be compared with the saving that may be reasonably expected by the change from hand to machine-milking. (The reports of Wisconsin farmers on this point, given in the Appendix, will prove of value in this connection.)

OPERATING EXPENSES. The cost of power for running two machines by the three-horsepower electric motor, was on the average 4 cents per hour, or about 6 cents per milking, i. e., about $3.60 month. This cost is on the basis of 5 cents per kilowatt, the price charged the University for power by the local electric company. This expense can possibly be somewhat reduced by the use of a gasoline engine, or a steam ejector, if the latter method of creating a vacuum proves practicable.

The cost of repairs for the machine after 20 months of constant use has amounted to less than $1. Several new escapement springs, worth about 25 cents in all, had to be put in. The

mouth pieces generally begin to wear out after about 6 months' use and have to be replaced, entailing an expense of 25 cents for each piece. With these exceptions, we have no reason to believe that any particular part of the machine is lacking in durability. Under the conditions under which the experiment was necessarily conducted, it is impossible to make comparisons of the cost of machine and hand-milking, or to state definitely the amount of saving, if any, the adoption of machine milking in our dairy herd of thirty-odd cows would involve, since some of the cows have always been milked by hand so far, and the experimental work in progress renders it necessary for the attendants to do much work that is not required on ordinary dairy farms. On this point of relative cost of hand and machine-milking we would refer the reader to the testimony of practical dairymen who are operating milking machines (see pp. 130–148).

It is evident that from a financial point of view alone the number of dairy farmers whom it will pay to install a milking-machine will be limited to those owning herds of fairly large size; but the difficulty of securing efficient help for milking and the uncertainty of the work done by ordinary milkers, will render it desirable to many farmers owning small herds to be able to attend to the milking personally by use of the machine and thus become independent of hired help in running their dairies. It is, therefore, manifestly impossible to lay down any absolute rules as to the smallest size of a herd in the case of which it will be advisable to introduce machine-milking. One farmer will worry more about the kind of milking done by his help than another and will be more anxious to place himself in a position to do the milking himself by installing a milking-machine if he is so situated that he can take care of the work alone, or with a minimum amount of help.

BACTERIAL CONTENT OF MACHINE-DRAWN AND HAND-DRAWN MILK

E. G. HASTINGS AND CONRAD HOFFMANN

The larger dairy farms of the country are, in many cases, producing milk for city markets in which there is a growing demand for better milk. This movement is finding expression in city ordinances establishing various standards other than those concerning the chemical composition of milk, which have been adopted in one form or another by most municipalities. In many cases the new standards are bacteriological, requiring that the milk contain not more than a stated number of bacteria per cubic centimeter. In order to meet these requirements, dairymen have found it necessary to improve the conditions of producing and handling milk. Since these standards are certain to find wider adoption than at present, one of the factors that will determine the success or failure of the milking machine, is the ability of the machine to draw milk that contains the minimum number of bacteria.

SOURCES OF CONTAMINATION

The sources of the bacteria found in milk, in the case of hand milking are: from the animal; from the clothes and hands of the milker; from the milk pails and from the air in the barn. There are subsequent sources of contamination, but these need not be considered in this connection, since they are identical on any particular farm, whatever the manner of milking may be.

The most important source of contamination with hand milking is the animal. Dust, dirt, and manure are constantly falling into the pail during the milking process. It is impossible to wholly prevent this contamination, which varies in extent with the condition of the animals as to cleanliness. Various means are employed to minimize this contamination, such as small topped or covered pails; clipping and washing the animals, etc. It would seem that the milking machine should exclude a large part of the contamination from the animal, the milker, and

the barn air, since the milk pail is closed and all air passing into the machine may be filtered through cotton.

The milk pail used in hand milking can be easily kept clean because of its simple construction. The milking machine is necessarily complicated and hence more difficult to keep in a clean condition than the more simple utensil. The studies which have been made, chiefly by Stocking,[6] have had to do largely with the various ways suggested for washing the machine and maintaining it in a clean condition.

CONDITIONS OF THE TRIALS

In the trials here reported no experimental work on methods of keeping the machine clean was done. The manner of washing and maintaining the machine was uniform during the entire period of use, and is described on page 95. The rubber parts of the machine were immersed in lime water between the periods of use. This, if prepared from good lime and an excess thereof maintained in the water, is of such a degree of alkalinity as will prevent the growth of all ordinary forms of micro-organisms. It will not, however, kill all forms of bacteria. It is practically impossible to free the rubber tubes completely from milk. If, however, the tubes are well washed, so as to remove dirt and all but a trace of the milk, and then completely filled with and immersed in good lime water as was done in these trials, no bacterial growth will take place between the periods of use. A number of examinations were made in order to determine whether this method of treating the rubber tubes was satisfactory and no evidence was obtained to indicate that it was not.

From what has been said, it is evident that the germ content of milk drawn by hand and of milk drawn by the machine, supposing that the utensils in both cases are bacteriologically clean, will depend upon the condition of barn and animals. Under the best conditions, where the contamination from the animals in hand milking is small, there should be very little difference in the germ content of hand and machine-drawn milk. With less satisfactory barn conditions, however, the difference should become more marked in favor of the machine.

---

[6] Conn. Storrs Expt. Sta. Bul. 42.

In the University barn no elaborate precautions are taken to prevent contamination in the case of hand milking. The cows are kept free from manure. Cleaning before milking is limited to wiping with a cloth to remove loose dirt. Open topped pails are used. The milkers wear milking suits, washed twice a week. In the trials the pails were treated exactly as the pails of the milking machine. It will be seen, however, from the data presented, that these precautions are sufficient in the case of hand milking to produce milk with a germ content comparing very favorably with that produced with far more stringent precautions. It was not to be expected that marked differences in favor of the machine would thus be found.

The results presented are wholly comparative, and are not to be considered the lowest attainable as regards bacterial content. The comparison of the two methods of milking was made with cows of the same degree of cleanliness, under identical barn conditions, and with utensils treated as nearly as possible in a similar manner.

Since one set of data is to be compared with the other, the bacteriological methods used in determining the number of bacteria are of little importance, however, a brief statement of methods used is necessary in order that one may judge of the relative results obtained.

The samples of milk from the individual animals were taken from the pails at the end of the milking of each particular animal. Plate cultures were made on agar having an acidity of +1 per cent, Mass. scale, containing 1 per cent of lactose. The interval between sampling and plating was about 16 hours. The bottles containing 50–100 cc of milk were kept in a refrigerator during this interval. The samples of mixed milk, results of the examination of which are presented in Table XIII, were plated in similar manner, four hours after collection. The plates were incubated at 37 degrees C for 48 hours and counted with a hand lens.

CLEANLINESS OF THE MACHINE

In order to determine the condition of the lime water in which the rubber tubes were immersed and the condition of the machine as to cleanliness, a number of examinations were made at irregular intervals. In Table X are collected the data obtained from the analyses of the lime water.

TABLE X.—BACTERIAL CONTENT OF LIME WATER USED WITH THE MILKING MACHINE.

Date.	Feb. 16.	Mch. 1.	Mch. 5.	Mch. 7.	Apr. 3.	Aug. 14.	Apr. 7.
Bacteria, per cc...........	72	25	100	180	125	14	225

The condition of the teat cups and rubber tubes was determined by passing varying quantities of sterile water through the cups and connecting tubes into the pail of the machine. From this water plate cultures were prepared. The data are given in Table XI.

TABLE XI.—BACTERIAL CONTENT OF WATER PASSED THROUGH THE MILKING MACHINE.

Date.	Dec. 19, 1906.	Jan. 11, 1907.	Jan. 15.	Mar. 12	Aug.14.	Aug.15.	Aug,21.	Apr. 7, 1908.
Quantity of water used pounds................	....	6	9	8	8	60	50	90
Bacteria, per cc........	100	30	190	70	1,300	570	690	180

It will be seen that even when large quantities of water were used, the bacterial content was considerable, and that the machines, as used in these trials, must accordingly be considered as one of the sources of contamination and quite an important one, when the total bacterial content of the milk is taken into account. The method used measured in some degree the contamination from the entire machine and not especially from the rubber tubes, which, as has previously been stated, were found to be in good condition, although they are supposed to be the most difficult portion of the machine to keep clean and sweet. With greater care, it is certain that the number of bacteria coming from the machine could be greatly reduced.

The samples of milk from the individual animals were collected from the pail of the machine and did not include the strippings which were drawn into an open pail. The samples were taken at irregular intervals during a period of about one year, and represent both summer and winter conditions. The period between successive examinations of the milk of any one animal varied from a day to several weeks. The results of the analyses are given in Table XII.

TABLE XII.—QUANTITATIVE BACTERIAL CONTENT OF MACHINE-DRAWN AND HAND-DRAWN MILK.

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MACHINE-DRAWN.																
Christina	1,170	18,170	390	100	600	540	980	890	1,090	1,000	2,350	....	....	....	....	....
Countess	310	2,770	17,650	5,330	3,110	11,750	3,810	3,530	1,750	1,460	1,690	1,230	....	....	....	....
Dorine	21,850	2,580	65,200	126,000	56,500	59,500	11,330	14,120	14,600	27,700	5,960	16,440	33,300	14,700	7,730	5,900
Double Time	15,700	490	9,000	2,720	310	8,800	1,500	10,600	....	....	....	....	....	....	....	....
Hannah	27,950	....	2,020	16,950	1,880	4,700	10,000	2,560	2,300	3,890	3,790	1,050	960	1,280	3,040	1,600
Josephine	2,460	2,160	6,270	3,230	5,580	2,470	950	1,170	1,940	4,240	2,060	2,490	2,440	1,770	....	....
Just in Time	1,140	1,830	1,960	3,820	5,630	2,680	1,740	1,410	2,490	2,210	2,170	2,950	....	....	....	....
Jewel	7,000	2,030	174,000	2,130	1,320	4,930	4,500	8,330	....	....	....	....	....	....	....	....
Jessie	660	1,530	121,000	1,390	10,100	32,700	4,830	1,930	1,260	3,070	2,020	4,190	4,480	1,010	2,050	9,410
Maggie	380	1,840	1,390	100	1,180	1,540	1,030	330	730	1,100	2,250	11,100	....	....	....	....
Ormsby	140	140	210	180	310	150	1,290	840	440	2,660	1,130	340	400	330	....	....
Perchance	3,070	890	790	2,260	2,530	410	1,510	590	4,770	1,310	1,250	320	....	....	....	....
HAND-DRAWN.																
Alma	5,510	1,370	4,410	4,300	4,640	2,450	4,880	4,520	....	....	....	....	....	....	....	....
Brownie	14,560	19,950	8,660	15,130	25,400	23,300	11,500	5,230	13,430	4,110	11,000	23,200	18,850	100,750	14,400	14,160
Irma	10,900	2,300	892,000	137,000	4,310	6,260	7,030	9,710	6,600	1,320	3,460	10,840	....	....	....	....
Jeanette	190	9,330	5,910	6,400	1,260	300	830	....	....	....	....	....	....	....	....	....
Johanna	600	320	1,190	4,460	7,290	19,330	32,800	....	....	....	....	....	....	....	....	....
Jewel	1,830	3,630	4,040	390	16,600	....	....	....	....	....	....	....	....	....	....	....
Joe	560	950	510	510	1,110	....	....	....	....	....	....	....	....	....	....	....
Muriel	1,730	6,860	27,000	4,330	16,260	3,480	2,050	2,840	3,180	2,370	2,590	....	....	....	....	....
Macella	3,650	870	1,580	630	560	1,020	920	2,070	1,020	1,560	2.440	56,500	6,140	6,530	....	....
Merney	2.480	1,080	150	370	1,420	3,530	1,700	170	270	....	....	....	....	....	....	....
Margaret	330	640	250	4,940	7,630	4,810	2,200	3,730	3,680	2,330	2,930	1,600	1,860	1,300	....	....
Marie	31,420	12,000	11,100	41,200	40,700	6,000	6,020	....	....	....	....	....	....	....	....	....
Mollie	1,130	190	180	1,610	....	....	....	....	....	....	....	....	....	....	....	....
Priscilla	14,300	1,230	2,180	500	1,330	....	....	....	....	....	....	....	....	....	....	....
Sadie	3,130	3,430	4,870	5,750	10,000	910	17,400	1,150	830	350	1,000	....	....	....	....	....

Some 150 samples of machine-drawn milk were examined. Of these, 75.3 per cent contained less than 5,000 bacteria per cc, 8 per cent between 5,000 and 10,000, and 16.6 per cent exceeded 10,000. Of the 135 samples of hand-drawn milk of individual animals examined, 63.7 per cent showed less than 5,000 bacteria per cc, 13.3 per cent between 5,000 and 10,000, and 22.9 per cent over 10,000. The results obtained were slightly in favor of the machine.

A comparison of the average number of bacteria found per cc in all of the samples of hand-drawn milk with the average number in the machine-drawn, as given in Table XII, is without value, as the variation between individual animals is so great. In samples No. 3 and No. 4, from Irma as many bacteria were found as in the remaining 133 samples of hand-drawn milk. The cause of the high numbers found in the samples mentioned was a slight attack of garget, not severe enough to be detected by the milker, and recognized only through a microscopic examination of the milk made for another purpose. Such results diminish very materially the value of data obtained from the examination of composite samples, unless the examinations are continued for long periods of time.

QUANTITATIVE BACTERIAL CONTENT OF COMPOSITE SAMPLES

During the spring a considerable number of composite samples of hand and machine-drawn milk were examined. While the

TABLE XIII.—BACTERIAL CONTENT OF COMPOSITE SAMPLES OF MACHINE-DRAWN AND HAND-DRAWN MILK.

Date.	Bacteria per cubic centimeter.		Date.	Bacteria per cubic centimeter.	
	Machine-drawn.	Hand-drawn.		Machine-drawn.	Hand-drawn.
March 6	3,800	1,800	May 4	1,500	300
" 10	7,100	1,500	" 5	11,300	700
" 11	2,160	200	" 6	6,300	5,800
" 13	3,450	2,700	" 7	6,400	1,200
" 16	5,300	2,500	" 8	4.500	1,200
" 18	20,900	14,900	" 13	9,300	4,300
" 20	12,850	9,500	" 14	900	5.000
" 23	5,600	47,600	" 16	25,700	1,300
" 25	6.500	64.000	" 18	2,200	2,300
" 27	8,200	800	" 19	11,200	2,000
" 30	10,000	4,700	" 20	1,500	1,300
April 1	3,700	5,600	" 21	4,400	2,000
" 3	3,100	900	" 22	9,000	3,100
" 6	600	1,000	" 27	4,400	2,100
May 1	1,100	600	" 28	7,000	3,000
" 2	2,900	760	" 29	9,500	2,700

objection previously mentioned to the comparison of composite samples holds true, it does not destroy the value of such data, unless some of the results depart widely from the normal. It will be seen from an examination of Table XIII in which are presented the data collected, that such variations are not marked.

The samples of milk were taken from a can containing about 10 gallons of milk. Of the 32 samples of hand-drawn milk, 78 per cent contained less than 5,000 bacteria per cc, 12.5 per cent between 5,000 and 10,000, and 9.4 per cent over 10,000. An equal number of machine-drawn samples were examined, 47 per cent of which contained less than 5,000; 34.3 per cent between 5,000 and 10,000, and 18.7 per cent over 10,000 bacteria per cc.

The results of the quantitative examination of the samples from individual animals and of the composite samples are summarized in Table XIV.

TABLE XIV.—COMPARISON OF HAND-DRAWN AND MACHINE-DRAWN MILKS EXPRESSED IN PER CENT OF TOTAL SAMPLES EXAMINED.

Bacteria per cc of milk.	MILK FROM SINGLE ANIMALS.		MILK FROM A NUMBER OF ANIMALS.	
	Hand-drawn.	Machine-drawn.	Hand-drawn.	Machine-drawn.
	Per cent.	Per cent.	Per cent.	Per cent.
Less than 5,000	63.7	75.3	78	47
Between 5,000 and 10,000	13.3	8	12.5	34.3
Over 10,000	22.9	16.6	9.4	18.7

From the above table it will be seen that in the case of samples from the individual animals the results are slightly in favor of the machine; with the composite samples the reverse is true. Factors of contamination enter in the case of the composite samples of machine-drawn milk which were not present in the case of samples from individual animals. After the machine was removed from the animal, the strippings were drawn into an open pail. Into this pail the milk was poured from the pail of the machine for weighing and sampling. It was then poured into a 10 gallon can from which the sample was taken. These additional sources of contamination undoubtedly are the cause

of the less favorable results obtained from the examination of composite samples of the machine-drawn milk.

From the quantitative data it is evident that there is no important difference between the hand-drawn and machine-drawn milks. The variations that occur are largely due to the difference in numbers coming from the udders of the individual animals. The germ content of both classes of milk could be reduced markedly by greater attention to details.

QUALITATIVE RESULTS

An attempt was made to determine the proportion of the different classes of bacteria present by the use of lactose-litmus-gelatine as recommended by Conn. No difference in the content of acid forming, liquefying and inert bacteria could be noted. The same is emphasized in a comparison of the keeping quality of various samples. The results are given in Table XV, from which it will be seen that the differences which are in favor of the machine are so small as to be of little practical significance.

TABLE XV.—RATE OF ACID DEVELOPMENT IN HAND AND MACHINE-DRAWN MILK.

	Sample.	Per cent of lactic acid after			
		24 hours.	48 hours.	72 hours.	96 hours.
Machine-drawn	1	0.16	0.18	0.20	0,75
	2	.16	.16	.57	.72
	3	.16	.18	.30	.75
Hand-drawn	1	.18	.21	.40	.80
	2	.18	.21	.83	.90
	3	.18	.20	.83	.90

LEUCOCYTE CONTENT OF THE MILK

One of the questions that has been raised in connection with the milking machine concerns its effect on the mammary gland of the animal. Any disturbance in the gland is likely to reflect itself in an increased content of white blood corpuscles in the milk; especially is this true if any inflammatory disturbance results. A series of determinations of the number of leucocytes present in the milk of a number of animals was accordingly

made before and after the introduction of the machine. The data are presented in Table XVI.

TABLE XVI.—LEUCOCYTE CONTENT OF HAND-DRAWN AND MACHINE-DRAWN MILK, IN THOUSANDS PER CUBIC CENTIMETER.

Name of animal.	Hand-Drawn.										Machine-Drawn.				
	10/21	10/22	10/23	10/24	10/25	10/26	10/27	10/28	10/29	10/30	A. M. 10/31	P. M. 10/31	11/1	11/2	11/3
Dorine	126	864	307	241	344	560	1060	525	262	750	531	310	791	491	564
Double Time	90	64	169	67	70	65	36	66	145	69	91	157	166	54	162
Floradora	99	50	111	100	137	102	55	137	77	41	71	86	79	77	107
Johanna	501	1157	970	654	232	275	49	52	49	....	51	30	46	25	55
Josephine	362	597	301	169	419	222	276	341	619	229	291	204	300	194	164
Just in Time	12	15	15	16	19	15	19	12	21	19	73	20	49	27	37
Laura	595	1166	685	3650	841	1329	1281	1266	2451	3627	822	510	307	494	1225
Maggie	264	185	664	1066	347	610	366	294	1214	581	481	335	981	512	614
Ormsby	99	182	79	269	175	151	187	210	167	250	194	150	125	142	162
Perchance	39	62	46	62	65	60	51	31	172	135	185	115	380	110	125

It was thought that if any bad effect resulted from the use of the machine, it should appear within a few days, hence the determinations were continued for only four days after the machine was placed in use. It will be seen that in no case is there any marked change. This would seem to indicate that no injurious effect was exerted on the udder by the machine, a conclusion which is substantiated by the report on the physical examinations given on page 108.

CONCLUSIONS

Under the conditions obtaining in these trials, the bacterial content of machine-drawn milk has been practically identical with that drawn by hand. The same is true of the keeping quality of the milk and of the qualitative bacterial content. It is not to be supposed that similar results would be obtained under different conditions.

With less favorable barn conditions undoubtedly the results would be more markedly in favor of the machine, in case it was kept in a sanitary condition. There is apparently no reason why the machine should not be so kept. The results farther than this depend on the intelligence and judgment used in operating the machine. Teats covered with manure and not well washed before milking mean dirty milk with machine, as well as with hand milking.

The results to be obtained depend entirely on the operator. Good milk can be produced with the machine, with no great expenditure of time and labor.

EFFECTS OF MACHINE MILKING ON THE UDDERS OF COWS

A. S. ALEXANDER

Since machine milking seems to be a radical change from the ordinary method of taking milk from the cow, owners reasonably might expect to see some apparent effects for good or bad in the condition of the cow's udder from the extended use of the mechanical apparatus. To determine the exact degree of change, if any, to be attributed to the action of the milking machine, a careful examination of the udders of the cows to be tested was made just prior to the beginning of the experiment, the examination embracing the shape, quality, condition and soundness of the udder; the shape, size, and position of the teats, and a report of the health, quality of skin, hair and general condition of each cow.

The udders were examined immediately after being milked out clean by hand, each quarter being handled separately and special attention being paid to the degree of pliancy of the skin and the presence or absence of hardening or other abnormal conditions such as indicate lack of perfect milk producing function. The size, shape and quality of the teats was noted for the reason that the machine might possibly cause alterations in the diameter, or length of the teats, or lead to either softening or hardening of the tissues, or possibly render certain cows harder or easier to milk. It also was thought important to note whether abnormally small or large teats had anything to do with the degree of perfection attained by the machine in milk extracting.

To serve as data for a correct comparison, a similar examination was made of the udders of 10 cows not entered in the machine-milking test, but hand-milked daily in the ordinary manner. Twice during the experiment and at its conclusion all of the cows were again examined in the same way and a careful comparison made of the conditions determined as present before and after the test with machine-milking and hand-milking. Four thorough physical examinations of the cows and their udders were made.

NO NOTICEABLE EFFECT ON THE COW

It will be of interest to farmers and dairymen to learn that the action of the milking machine had no appreciable effect upon the general health of the cows tested. They speedily became accustomed to the apparatus and soon learned to stand quietly, showing no nervous irritability. Throughout the six months' trial they retained their normal condition in a majority of cases, and a few slightly improved in physical condition.

The machine milking had no apparent effect as regards the condition, quality, texture, or form of the udders of a majority of the cows used, nor did the teats increase in length, change in texture, or become less in calibre by reason of the mechanical suction to which they were subjected. Some improvement was quite noticeable in the udders of three of the cows at the conclusion of the test, slight hardenings previously noticeable having disappeared. In two other cases, however, where indurations had been quite noticeable at the beginning of the experiment, the conditions had become aggravated appreciably during the test. The improvements noted may have been due to the thorough manipulation or massage of the udder which is done in connection with machine milking, while the aggravations could scarcely be attributed with certainty to the action of the machine, as similar aggravations were noticeable in like conditions found in the udders of cows milked by hand and used as checks in the experiment.

It may be concluded that, so far as this test is concerned, for the period of time covered, machine milking had no appreciable effect upon the physical condition of the cows used, nor did it in any way affect the udders of a majority of the animals. It was apparently responsible for improvement in the udders of three of the cows, and in two instances possibly caused aggravation of abnormal conditions previously noted.

The results from machine milking, therefore, would seem to warrant the conclusion that little is to be feared as regards the health or contentment of the cows used, and that no bad effect upon their udders may be looked for, provided the condition of the glands is normal at the outset, and attention is paid to hand stripping in particular cases.

EXPERIENCE OF WISCONSIN DAIRY FARMERS WITH THE B. L. K. MILKER

Since so much depends upon the management of the herd and the method of operating the milking machine it was considered desirable to ascertain the experiences of Wisconsin dairymen who installed this machine at about the time it was placed in the University barn, or afterwards. Efforts were accordingly made to secure accurate information as to the results obtained with the machine by all such dairy farmers in this state whose addresses could be secured. By correspondence or personal interviews answers were obtained to questions relating to the experiences of 41 different Wisconsin farmers who had used the milking machine for periods ranging from one to 26 months. The farmers whose names are given in the list given in connection with the data (see Appendix, p. 128), courteously reported their experiences with the milking machine. Thirteen of these reports were received last year when it was planned to issue a progress report on our results with the milking machine. At the completion of this investigation, 15 months later, second reports from these farmers were secured in the same manner as the previous year, which gave the experience of these parties with the milking-machine after the time their first reports were made; a second report was also received from three other farmers, making 41 reports and 16 second reports in the aggregate.

The reports obtained from the different farmers have been carefully summarized and the main results are embodied in the Tables XXI to XXIII, in the Appendix.

It is impracticable to discuss in detail the reports of the various farmers whose experiences with the milking-machine are here summarized. The reader should carefully study the figures and views submitted by these farmers with regard to their experiences with the milking-machine, in order to give due weight to the testimony presented.

ANALYSIS OF THE OPINIONS OF FARMERS

If we summarize the reports and the opinions of the farmers with regard to the operation and general practicability of the milking-machine, as based on their personal experiences with the

machine for periods ranging from a few months to over two years, we find that of the 41 first-reports received, 31 were favorable to the machine, 8 were undecided, and 2 unfavorable. Of the 16 second-reports received, 8 were favorable, 3 undecided, and 5 unfavorable. Since one farmer reported unfavorably both times we have, therefore, 6 different dairy farmers, out of a total of 41, whose reports were unfavorable to machine-milking under the conditions existing on their farms.

An analysis of these reports shows that the general conclusion with regard to the lack of practicability of the milking machine is based on one or more of the following reasons: Five reported, "Cows not doing as well as by hand-milking"; five, "No saving in help"; two, "Bad effect on the udder"; two, "Deleterious effect on flavor of milk and cream"; two objected to the labor of washing and care of machine, and one each gave "No saving in time" and "Lower fat content of milk obtained on machine-milking" as their objections to the milking-machine.

Three of these farmers, whose reports were more or less unfavorable to the machine, have pure-bred herds and sell their surplus stock for breeding purposes. Each of these breeders discontinued the use of the machine after a trial of a few months only, on the ground that it did not get as much milk as it should. The two others who were not satisfied with the yields obtained are careful dairymen that doubtless look more closely at the returns from their herds than is the case with the average farmer. The sixth farmer is also apparently a careful and thorough dairyman, though perhaps lacking in mechanical ingenuity and resourcefulness. He reports that cows milked by machine seem to do well, but more than one-third of his herd is hand-milked, the plan being to machine-milk those cows that respond more to this method and these only during the earlier part of their lactation.

Only one of the six breeders found any saving in help by the use of the machine under his conditions of farming, as enough men are required for other farm work to do the milking by hand without difficulty. With one exception these herds have the direct and careful supervision of the owner and in many cases he himself has been one of the operators of the machine. As stated, most of these men discontinued the use of the machine after a brief trial which may be considered hardly long enough to thoroughly familiarize the operator with its manipula-

tion, or accustom the cows to machine-milking. In a valuable herd of pure-bred cows, it is certainly a question whether it would be wise to continue such an experiment for even a short time if the cows failed to do well. Even a decided saving in help might not be economical if the method of milking should damage the udder or decrease the production of the cows, or fail to develop the milking qualities of the heifers.

IMPORTANCE OF THE OPERATOR

There is another point brought out in these reports and by observation at different dairies where machine-milking is practiced, that should receive some attention. All men are not equally successfully in running the machine, and on the same farm and with the same cows one man may make much better time with the machine and get better returns from the cows than another. The result is that he soon has the heavy share of the work of milking to do and, as a consequence, may in time be unable to see many advantages in machine-milking. This is a fault in management and can be overcome by more consideration in the division of labor and by making proper arrangements with new help.

SUMMARY OF EXPERIENCES

Of the 16 farmers who submitted two reports, seven reported favorably on the machine both first and second time, two were undecided, and one gave an unfavorable report both times. Two changed from favorable in first report to unfavorable in second report; one from favorable to undecided; one from undecided to favorable, and two from undecided to unfavorable. Of the 41 farmers reporting, 31 submitted favorable reports either the first or the second time, while 27 submitted only favorable reports. We may consider, therefore, that we are justified in concluding that 27 out of 41 farmers were able to make a success of machine-milking under their conditions of farming with the present development of the milking-machine, while six out of this number were unable to do so.

It is evident from the comments made in the reports given that the success of machine-milking will depend largely on the man operating the machine and on his attitude toward machine-milking. If he is willing to give the machine a fair trial

and to follow the directions of the manufacturers he will, as a general rule, be able to make a success of this method of milking, at least to the extent of approximating the results obtained by good hand-milkers, and perhaps even improving on those secured by general farm help, who are often prejudiced against the work of milking.

RESUMÉ OF THE INVESTIGATION

The trials reported in this bulletin were made with the B. L. K. milking machine during a period of 20 months; 29 different cows in the University dairy herd were included in the trials. Of this number, 11 were machine-milked during two different lactation periods, making 40 separate trials that have been conducted during the period stated. The individual cows were machine-milked for continuous periods of four to 62 weeks, the average length of the trials being 26 weeks. The following conclusions seem warranted by the results obtained in this investigation.

EFFECT ON PRODUCTION

Most of the cows took kindly to the machine, stood better, and appeared to be less disturbed when machine-milked than when hand-milked. The immediate effect of the change from hand to machine-milking on the production of milk and butter fat was no more pronounced than in the case of a change of regular hand milkers. Considering the entire period during which the cows were machine-milked, there was an average decrease in their weekly production of 2.9 pounds of milk and 0.12 pound of butter fat. These figures are identical with corresponding figures for hand-milked cows kept under similar conditions.

The average weekly production of the cows on the trials for the machine milking periods was 145.8 pounds of milk and 6.19 pounds of fat per head. This is 16.6 pounds less milk and 0.53 pound less butter fat than the entire herd averaged the year preceding these experiments, and 14.3 pounds less milk and 0.63 pound less butter fat than the average data for the preceding winter period for the entire herd. The average production of the cows on the machine milking was therefore somewhat lower than that of the entire herd for earlier periods on hand milking, but it is possible that the fact the cows were older during the

machine-milking trials than when milked by hand was of importance in bringing about this result.

If the production of the same number of cows during the machine-milking be compared with preceding periods of hand-milking, it will be found, as the average for 10 cows (15 different trials), that the weekly decrease in production was practically the same for both methods of milking, while the average production per week for these cows was 10.6 pounds less milk and 0.42 pound less fat on machine milking than on hand-milking. The average age of the cows was nearly eight years at the middle of the milking-machine trials, and it is, therefore, likely that the fact that the cows were older when milked by machine than during the hand-milking periods has been a factor in determining the latter results. Four of the cows produced over 10 pounds of butter fat per week on the average for the periods they were machine-milked (4 to 33 weeks, average 23 weeks), the highest weekly production on the machine-milking being that of Macella (12 pounds butter fat per week, as an average for a period of 33 weeks), and Dorine (11.55 pounds of butter fat, average for 22 weeks). Both of these figures show the highest production ever reached by these two cows for periods of similar length and at corresponding stages of their lactations when they were milked by hand.

Under the conditions of these trials, we feel justified in concluding that both the average production of the cows on machine milking and the decrease in production with the advance of the lactation within the period of these trials compare favorably with corresponding figures for hand milking, and show that it is possible, by proper management and care of the machine, to maintain nearly as high a production of milk and butter fat as when the cows are milked by hand.

During the pasture season of 1907 when the importance of keeping the vacuum below 16 inches in operating the milking-machine was less understood than it is now, the machine-milked cows in the herd decreased more rapidly in production after a period of about four months when a vacuum of 16½ to 17 inches had been maintained than did a corresponding lot of hand-milked cows. During the summer season of 1908 when the vacuum was kept at 15 to 15½ inches, there was no appreciable difference in the way in which the machine-milked and the hand-milked cows were able to maintain their secretion of milk and

butter fat on pasture or at other periods. Special attention must, however, be given to the proper adjustment of teat cups and mouth pieces at this time as it may be necessary with some cows to change to smaller sizes during the pasture season.

STRIPPING AFTER MACHINE MILKING

Judging by the amount of strippings obtained, it appears that most cows will become accustomed to the machine in from one to ten weeks, after which time the weight of the strippings will, as a rule, remain practically constant for each cow, at an average of a little over two pounds per week, or about two ounces per head for each milking. The results of machine milking four cows for a period of 12 weeks without stripping, gave no decided indications that stripping is necessary in all cases. Further investigation covering the necessity of stripping, must, however, be made before any definite conclusion on this point can be drawn.

A few cows in the herd persisted in withholding a considerable amount of milk from the machine, and doubtless such cows will be found in most herds; these will necessarily have to be stripped or disposed of, if the machine is depended upon altogether for doing the milking. The same holds true in the case of old cows and such considerably advanced in lactation, having abnormal teats and udders, in size, shape, and quality, or such as are of a nervous or obstinate temperament, all of which will be found more or less difficult to machine-milk in a satisfactory manner.

TIME SAVED BY MACHINE-MILKING

A time experiment in which one attendant with two machines milked and stripped 12 cows, showed that the time required to milk these cows ranged from 31 to 40 minutes, or an average of slightly less than three minutes per cow. This gain of about five minutes per cow on the average time that is generally required for hand-milking, is secured by four cows being milked at the same time where two machines are used, and not by the rapidity of the work of the machine. On ordinary dairy farms it may be practicable for one man to attend to three machines, which would still further expedite the milking. Ten to 20 minutes were required for the attendant to get two machines ready for milking, and 20 minutes to clean scrupulously all parts after

the milking was done. The cost of power for operating two machines by the use of a 3 H. P. electric motor amounted to about 4 cents per hour; this is doubtless more expensive than would be the case on most dairy farms, where other power is employed.

EFFECT ON CLEANLINESS OF THE MILK

The frequent examinations made by the Bacteriological Department (see p. 98) showed that the machine was always in excellent condition as regards cleanliness. It was also found that under the conditions of these trials, the milking-machine as a rule produced milk with a slightly lower bacterial content than that drawn by hand, which is rather low in bacteria, owing to the good sanitary conditions at the dairy barn. There was but little difference in the keeping quality of milk drawn by the two systems, but the difference was always in favor of the machine. The strict adherence to the directions of the manufacturers for operating and caring for the machine and the painstaking manner in which the teat-cups and mouth-pieces were adjusted to the various cows doubtless account for the efficiency of the machine during the trials.

EFFECT ON THE HEALTH OF THE COWS

The examinations made by the Veterinarian and reported on page 107, showed that during the period covered by the trials of the milking-machine in the University dairy herd, machine-milking had no appreciable effect upon the physical condition of the cows used, nor did it in any way affect the udder of the majority of animals. It was apparently responsible for some improvement in the udders of three of the cows and in two cases possibly caused an aggravation of abnormal conditions previously noted.

The conclusion would seem warranted, therefore, that little is to be feared by adopting machine-milking as regards the health or the contentment of the cows used and that no bad effects upon their udders may be looked for, provided the condition of the glands is normal at the outset and attention is paid to hand-stripping in particular cases. In these tests the results from machine-milking compared favorably with those obtained from the hand milking of a like number of cows during the same length of time.

EXPERIENCES OF PRACTICAL DAIRYMEN

The replies to inquiries sent to Wisconsin dairymen who have used the B. L. K. milking-machine in their herds are, in so far as the experience of these farmers goes, in the majority of cases favorable to the machine. Some 27 out of the 41 different farmers reporting their experiences with the milking-machine were, in general, favorable to this method of milking; eight were undecided, and six reported unfavorably. The experiences of these farmers extended over periods from a couple of months to over two years and covered a wide range in the conditions under which the dairies were conducted.

If the data at hand are sufficient to permit of generalization, it may be said that, under the conditions of dairy farming prevailing in this state or country and represented by the reports received from practical dairy farmers, about 67 per cent of farmers installing the machine, or two out of every three, will be able to make a decided success of the machine, and 14 per cent will be likely to fail, or will discontinue the use of the machine for various reasons, while the experiences of about 19 per cent will be such as to make them rather undecided as to the advantages and practicability of this method of milking.

The success of machine-milking will depend largely upon the man operating the machine and on his attitude toward machine-milking. If the machine is given a fair trial and the directions of the manufacturers are carefully followed, machine-milking will, as a general rule, be a success, at least to the extent of approximating the results obtained by good hand-milkers and perhaps even improving on those secured by general farm help. It would appear from the reports submitted that in herds of 30 cows or more, the milking-machine is both practical and economical, and will be likely to give good satisfaction. For smaller herds the machine will enable the farmer to become largely independent of hired help, as he can operate the machine himself, with the aid of perhaps a boy, and thus avoid keeping extra help for milking.

GENERAL CONCLUSIONS

The experiences of practical dairy farmers and the results of careful exhaustive trials agree in showing that so far as the machine itself is concerned, the problem of mechanical milking

may now be considered solved, although minor improvements in the present machine are needed and will doubtless be made before long. It will, therefore, depend on the individual dairy farmer whether machine-milking can be made a success under his special conditions of dairying.

The adoption of machine-milking can only be recommended under conditions where the farmer is able to give personal attention to the operation of the machine, or has reliable intelligent help who can and will follow the directions of the manufacturers as to care of machine, manipulation of the udder, stripping the cows, etc. Where such is the case we can recommend the milking-machine for the general dairy farmer who has a large herd, or for farmers owning smaller herds, e. g., 30 head or perhaps less, who will be able to attend to the milking of the herd, alone or with the help of a boy, by means of the machine and thus avoid keeping extra help for this purpose.

We do not feel perfectly safe in recommending the milking machine for pure-bred herds where the maintenance or development of a maximum dairy production in the cows is of vital importance, although we believe that under favorable conditions it may also prove of value in such herds.

Properly cared for and handled the milking-machine will prove a valuable aid in the solution of the hired-help problem on many dairy farms and will become an important factor in the further development of our dairying industry.

APPENDIX.

HISTORY OF THE B. L. K. MILKING MACHINE.

The following condensed statement of the history of the B. L. K. milking machine was furnished by the manufacturers. This gives the practical experience of the manufacturers in the early trials conducted with the machine at their own farms:

"In May, 1860, patents were granted to L. O. Colvin, covering a milking machine which consisted of teat-cups connected with a hand suction pump and which were either mounted on the pail or held in such a way that the milk was discharged freely into the pail, which was placed beneath. These devices were tested by Mr. D. H. Burrell on his father's farm. Since that time we have carefully watched the development of the cow-milkers, and have thoroughly investigated all of the more promising inventions brought out, both in this and in foreign countries, but all proved to be failures until Lawrence & Kennedy invented their pneumatic pulsator.

"In 1895 we installed at one of our large dairies, the 'Thistle' Milking Machine, manufactured under the patents granted to Alexander Shiels. This milker was a great improvement over all prior devices, as Shiels was the first to produce vacuum pulsations in the teat-cups by admitting air. The system had, however, some fatal defects. First of all, the vacuum pulsations were produced in the entire vacuum system by a mechanically operated pulsator located at the pump. The pulsations in the teat-cups were never very sharp or well-defined, and of course could not be, and while the milking was somewhat better than that obtained by a continuous suction, still it was not all that it should be; it was simply a step in advance. Also, with this system it was exceedingly difficult to keep the piping clean and in sanitary condition on account of the very large amount of air that had to be carried through the pipes at each pulsation, and also, on this account, the pump had to be very large. At our own dairy it required about 10-H. P. to operate it.

"Messrs. Lawrence & Kennedy made a vast improvement over the Shiels and all other systems. In place of producing vacuum pulsations throughout the entire system, they located a pneumatically operated pulsator on top of the milk pail, and were then able to produce sharp vacuum pulsations in the teat-cups. The power required to operate the milkers was reduced to one-sixth or one-eighth of that required for the 'Thistle' system, and because all pulsations were stopped in the pipe line, it was possible to keep this clean; and best of all, the sharp and well-defined pulsations rendered the device practical, so that it would milk the cows clean.

"This invention of a pneumatically operated pulsator, producing vacuum pulsations in the teat-cups, Messrs. Lawrence & Kennedy were able to protect by broad foundation patents taken out in all the principal countries of the world, and it is now recognized in all the dairy countries that this invention changed the milking machine from something totally unpractical to a practical, simple, successful system.

"We received four of the Lawrence & Kennedy machines in the summer of 1902, and in September of that year started them at work in our Overlook dairy. We planned and carried out a careful system of tests, and while we found that the machine as then constructed embodied the basic principles necessary for success, still we did not consider it in all respects a practical machine for the regular dairy use of our farmers. In September, 1903, we started work in earnest to design and construct a machine, having first obtained a license from Lawrence & Kennedy under their patents, that would be perfectly adapted to all requirements of the farmers of the United States, and in January, 1904, we had in use a device that would milk regularly any of our cows—some that we had been previously unable to milk—and also we had a pulsator that could be instantly taken apart to clean without the aid of tools.

"In May, 1904, we had progressed sufficiently to install the machines at another of our farms, where they have been in constant successful use ever since. The first machines were placed on the market in April, 1905."

NOTES ON BEHAVIOR OF COWS ON MILKING-MACHINE TRIALS.

ADELAIDE. (Ayrshire.) Did not object to machine. Did not milk out very well at first, but later left only 0.4 to 0.5 pound of strippings to be milked out. Udder of good quality and form. Teats rather small and close together, but even in size. Put on machine 10 weeks from time of drying off. Milked on left side. No. 1 T. C.[1] last year, this year No. ½ T. C.

AGGIE. (Holstein.) Took kindly to machine and stood quietly. Milked out well (0.1 pound strippings to the milking). An easy milker. Required very little manipulation. One of the best cows on the machine. Improved in production after being placed on the machine. Udder a little meaty but good for a heifer. Teats nice and well placed, short and blunt. No. ½ T. C.

ALMA. (Holstein.) The machine seemed to be unable to remove the milk unless forced into teats by manipulation. She stepped about while being milked and never stood as quietly as when milked by hand. Naturally a hard milker. She gave gargety milk toward the end of the lactation period, but it is not likely this was caused by the machine, for she has been subject to garget in earlier years when nearly dry. Of a nervous disposition, easily excited; udder large and meaty; teats well placed; quite short, thick and blunt; left fore teat projecting away from body. The udder seemed to have a surplus of loose skin that hung down over the teats. This was especially true with left fore quarter. No. 3 T. C. on left front teat, No 2. on other three.

BROADWAY. (Jersey.) Gave about two pounds of strippings to the milking. Did not respond as well to machine milking as some others; was somewhat restless on machine-milking. Had a pendulous udder of coarse quality, long teats. Disposition sluggish, inclined to be fat. No. 5 T. C.

CHRISTINA. (Ayrshire.) Always left a good deal of milk to be stripped out and required considerable manipulation. Did not object to machine. Udder fairly evenly developed, although left side somewhat smaller than right side; rather meaty. Teats somewhat close together behind and

[1] Teat Cup number.

small. Last year No. 0, T. C. was used on right hand teat, No. 1 on other three; this season all No. ½ T. C. used.

CLARA. (Brown Swiss.) Objected to machine milking. Milked from the left side. Had to manipulate considerably, almost continuously. Stood alright for hand milking. Kicked and would hump up when machine was put on. Udder coarse, teats large and well placed. A rather hard milker. Nos. 5 and 4 T. C.

COUNTESS. (Guernsey.) Worked well from the start on machine milking. Began to hold up her milk until she was fed at time of milking. This practice continued until the end of the lactation period, Oct. 1. Good quality of udder, a little uneven. Front quarters deficient. Teats long and slender, an easy milker. No. 1 T. C.

COZIE. (Grade Guernsey.) Took kindly to machine milking. Udder of good quality, square and fair sized, teats small, close behind, tapering. Operated on for tumor five weeks after being placed on machine. No. ½ T. C.

DORINE. (Grade Guernsey.) Took kindly to the machine from the first; was accustomed to being fed at milking time, which practice was continued through the entire milking-machine period, except for a week (July 10–16) when a marked decrease in milk production resulted, also irregularity in the amount of milk for the different milkings. Udder large and somewhat pendulous, right half larger than left, of good quality, although not of quite as good quality during second trial as in the first trial; shape of udder better and quality improved after machine milking began the second week from calving; teats well placed, quite large and tapering. An easy milker. Nos. 5 and 4. T. C. first year, second year No. 5.

DOUBLE TIME. (Jersey.) Took kindly to machine from the first and never failed to let down her milk. Had been in the habit of being fed at milking time, which practice was also followed when machine milking commenced. The manner in which she kept up in production was undoubtedly greatly influenced by this practice. Her udder of superior quality, evenly balanced; teats tapering, of medium size and well placed; naturally a very easy milker. Nos. 2 and 1 T. C.

FLORADORA. (Guernsey.) Did not let down her milk readily at any time; required much manipulation at all times; toward latter part of the lactation period it was found necessary to manipulate a minute or two before attaching the machine. "Dish-rag-udder", teats close together and rather small. No. 1 T. C.

GOODWIN. (Jersey.) Nervous disposition. Restless at first on machine milking (also on hand milking). Left front teat cannot be milked clean by machine, must be stripped by hand. Uneven udder, fair quality. Teats long and slender, well balanced. Left 0.4 to 1.0 pound of strippings per milking, mostly from left front quarter which was lower than other part of udder and shorter rubber connection therefore required. Required considerable manipulation. Kept up an exceptionally uniform production on four months' machine-milking. No. ½ T. C. used at first, changed after about two weeks to No. 0. No. 00 teat cups might have done better than No. 0.

HANNAH. (Guernsey.) Did very well on machine. Stood quietly when

machine milked and did not require much manipulation. Udder of good quality and form; short, rather blunt teats, easily milked. No. ½ T. C.

JESSIE. (Guernsey.) Took kindly to and did very well on machine (made advanced registry A. G. C. C. on machine-milking). Quality of udder improved during progress of trials. Teats well placed, close together behind, rather small. Ran very even in production. Milked out very well (0.1 to 0.2 pound per milking.) Requires a good deal of manipulation. No. 1 T. C. at first, changed to No. ½ size after a short time.

JEWEL. (Jersey). Udder very uneven, especially left front quarter which is very deficient in size. Extra outfit required (1 teat cup with extra hose attached). Quality of udder fair. Stood nicely for machine and did not require much manipulation. Milked out very well (0.2 pound maximum strippings). No. 1 T. C.

JOHANNA. (Holstein.) Stood quietly and milked out without much manipulation; never objected to machine; fed before milking Good quality of udder, hind teats very short and tapering. An easy milker, but slow to milk by hand on account of her short teats. Seemed to keep up better in milk flow up to the time of calving when hand milked than in 1906; hard to get her dry ordinarily (48 days dry after machine-milked, 27 days after hand-milked). Nos. 1 and 0 T. C. The mouth-pieces on hind teats were perhaps rather small.

JOSEPHINE. (Holstein.) Did not take kindly to machine at first and required considerable manipulation; slow in letting down milk and did not always act the same way; sometimes she would only give a few tenths of a pound of strippings, and at other times several pounds. Her udder is of good quality; teats long and slim; a fairly easy milker. Nos. 2 and 1 T. C.

JUST IN TIME. (Jersey.) Did not take kindly to machine at first, would hold up part of milk at times, sometimes giving down milk when stripping started, and at times persisting in holding it up. On several occasions, 20 to 30 minutes afterwards her teats would be full, and judging from the condition of her udder, would evidently have given several pounds. Inclined to be nervous when visitors were around. Nos. 2 and 1 T. C. used first year and part of the second; No. ½ the rest of the time.

KATE. (Holstein.) Udder of good quality, somewhat uneven; left side not as well developed as the right; long, tapering teats. Fed during milking. Did not object to machine-milking. At first was not stripped and did fairly well; later on left more and more milk to be stripped out. An easy milker. Nos. 2 and 1 T. C.

LAURA. (Jersey.) Did fairly well on machine milking, but required considerable manipulation at all times. Manipulation made more difficult and less effective on account of enlargement and hardening of left quarters of udder. Her udder of coarse quality for a Jersey. Nos. 3 and 2 T. C.

MACELLA. (Jersey.) A very satisfactory producer, her record this year better than last year when hand-milked; had milk fever after both calvings. Udder meaty and did not milk down thoroughly, slow to milk out toward last after machine-milked, required more manipulation than cows with "dish-rag-udders." Milked right out by hand. Good teats, well

placed, an easy milker. Fore quarters somewhat less developed than hind ones. Nos. 2 and 1 T. C. at first, changed to No. 1 after short time.

MAGGIE. (Holstein.) Did not take kindly to machine; while she did not fight it, still she would not give down her milk regularly until fed at milking time. Required much manipulation at all times. Machine milking satisfactory during second trial after freshening in fall of 1907. Udder not of very good quality. Teats large and blunt and seemed too large for No. 5 T. C. Ends of teats chafed and red at first, but after a few weeks this was not noticeable. No. 5 T. C.

MAXIE (Holstein.) Stood better on machine-milking than on hand-milking. Very uncertain, nervous, could not be left when machine-milked. A slow milker. Requires a good deal of manipulation, more than any other cow in the herd. Very uneven in amount of strippings. Apparantly dry when through on machine-milking, but gives down more milk on stripping. Udder funnel-shaped, front quarters somewhat deficient; short teats. Nos. 2 and 1 T. C. at first, then No. 1, second trial No. ½.

McGEOCH. (Grade Holstein.) Objected somewhat to machine-milking owing to sore between front quarters. Milked on left side. Large fleshy udder; good size teats, well placed. Deficient in right front quarters. No. 5 T. C.

ORMSBY. (Holstein.) Stood quietly and seemed to enjoy being milked by machine from the start. Teats long and very slim. Udder of very good quality ("dish-rag-udder"). Did not require much manipulation. A very easy milker. No. 1 T. C.

PERCHANCE. (Jersey.) Was rather obstinate and objected considerably to machine at first. Would kick and step about while machine was being attached until feeding at milking time was commenced; milked on the left side during the first trial which apparently was the cause of her dislike for the machine. Milked on the right side during the second trial. Udder uneven in quarters, good sized; medium sized teats. Nos. 3 and 2 T. C. used part of first year; second year Nos. 2 and 1 at beginning, afterward No. 1 used on all teats.

PRISCILLA. (Ayrshire.) Did not like machine milking; kicked when machine was put on. Worst at beginning of trial and just before being dried off. Milked on right side. Teats smooth, no reason apparent for her objecting to machine. Varies in the amount of strippings left. Udder of good quality. Teats even, small and fine, close together behind. No. ½ T. C. last year, this year No. 0.

QUEEN. (Guernsey.) Did not milk out evenly; at first left 0.3 to 0.4 pound in strippings, later on did better. Quality of udder good, front quarters deficient, somewhat pendant udder; teats pretty well placed, fair sized, tapering. Objected strongly to machine milking at first and dropped off greatly in milk at the beginning of the trials. Tried several outfits before coming back to the one used first. No. 2 T. C. on right front teat and No. 1 on other three teats at first, changed in a few weeks to No. 1 for all teats.

SADIE. (Jersey.) Took well to milking machine, although milked on wrong side. Udder small, of good quality; front teats of good length, tapering. An easy milker. Gave 0.1 to 0.2 pound of strippings, not over 0.2 pound. Nos. ½ and 0 T. C. at first, afterwards changed to No. ½.

TABLE XVII.—WEEKLY PRODUCTION OF DORINE DURING PERIOD OF MACHINE MILKING.

DATE.	Milk.	Fat.		STRIPPINGS		
					Per cent of total production	
	Lbs.	Per ct.	Lbs.	Lbs.	Milk.	Fat.
1906.						
Oct. 17-23....	160.0	5.58	8.93	*....	....	....
24-30....	155.9	5.53	8.63	....	....	....
31-Nov. 6	137.5	5.56	7 64	3.8	2.8	3.1
Nov. 7-13....	140.3	5.56	7.80	2.6	1.9	2.0
14-20....	142.0	5.62	7.98	1.7	1.2	1.3
2 -27....	136.2	5.45	7.42	1.3	1 0	1.1
28-Dec. 4	124.7	5.60	6.98	†1.5	1.2	1.3
Dec. 5-11....	119.5	5.60	6.69	1.4	1.2	1.3
12-18....	124.0	5.55	6.88	1.4	1.1	1.3
19-25....	115.9	5.55	6.43	1.4	1.2	1.3
1907.						
Dec. 26-Jan.1	111.9	5.73	6.41	‡1.7	1.5	1.7
Jan. 2- 8....	116.5	5.58	6.50	2.1	1.8	2.0
9-15....	109.9	5.80	6.37	1.5	1.4	1.5
16-22....	99.9	5.58	5.57	1.4	1.4	1.5
23-.29...	93.9	5.58	5.24	1.4	1.5	1.6
30-Feb. 5	89.7	5.73	5.14	1.4	1.6	2.0
Feb. 6-12....	91.3	5.68	5.19	1.4	1.5	2.0
13-1'....	93.9	5.63	5.29	1.4	1.5	1.9
20-26....	94.4	5.60	5.29	1.1	1.2	1.5
27-Mar. 5	94.5	5.68	5.37	1.1	1.2	1.5
Mar. 6-12....	89.5	5.58	4.99	1.0	1.1	1.5
13-19....	93.3	5.88	5.49	1.3	1.4	1.8
20-26 ...	90.6	5.55	5.03	1.3	1.4	1.9
27-Apr. 2	91.0	5.50	5.01	1.4	1.5	2.0
3- 9....	91.1	5.63	5.13	1.6	1.8	2.3
10-16....	91.4	5.60	5.12	1.5	1.6	2.1
17-23....	87.6	5.53	4.84	1.6	1.8	2.4
24-30....	83.4	5.53	4.61	1.4	1.7	2.1
May 1 -7....	87.3	5.58	4.87	1.4	1.6	2.1
8-14....	91.6	5.50	5.03	1.4	1.5	2.0
15-21....	87.2	5.60	4.88	5.2	6.0	7.8
22-28....	83.0	5.65	4.69	4.6	5.5	7.2
29-June 4	84.3	5.00	4.22	1.7	2.0	2.6
June 5-11....	84.2	5.10	4.29	1.7	2.0	2.6
12-18....	86.1	5.18	4.46	1.4	1.6	2.1
19-25....	84.3	5.05	4.26	1.5	1.8	2.3
26-July 2	86.5	5.10	4.41	1.4	1.6	2.1
July 3- 9....	79.1	4.83	3 82	1.6	2.0	2.6
10-16....	65.3	5 78	3.77	1.4	2.1	2.7
17-23....	70.2	5.45	3.83	1.4	2.0	2.6
July 24-30...	71.6	5.53	3.96	1.2	1.7	2.2
31-Aug. 6	70.7	5.48	3.87	1.4	2.0	2.6
Aug. 7-13....	65.7	5.40	3.55	1.4	2.1	2.7
14-20....	64.1	5.45	3.49	1.3	2.0	2.6
1-27....	61 8	5.58	3.45	1.4	2.3	3.0
28-Sept. 3	59.2	5.33	3.16	1.2	2.0	2.6
Sept. 4-10....	52.9	5.68	3.00	1.8	3.4	4.4
11-17....	38.2	6.15	2.35	1.3	3.4	4.4
18-24....	43.8	6.00	2.63	1.5	3.4	4.4
25 Oct. 1	40.6	5.65	2.29	1.5	3.7	4.8
Oct. 2- 8....	40.9	6.13	2.51	1.5	3.7	4.8
9-15....	38.3	5.80	2.22	1.4	3.7	4.8
16-22....	33.6	6.05	2.03	1.4	4.2	5.5
23-29....	28.4	6.05	1.72	1.5	5.3	6.9
30-Nov. 5	25.7	6.20	1.59	1.1	4.3	5.6
6-12§....	25.1	6.20	1.56	....	....	....
1908.						
Jan. 22-28....	226.8	5.50	12.47	....	....	....
29-Feb. 4	242.0	5.85	14.16	5.2	2.1	4.0
Feb. 5-11....	232.2	5.70	13.24	5 1	2.2	4.2
12-18....	239.5	5.50	13.17	6.6	2.7	5.1
19-25....	237.3	5.33	12.65	5.5	2.3	4.4
26-Mar. 3	225.0	5.53	12.44	3.7	1.6	3.0
Mar. 4-10....	229.6	5.40	12.40	4.1	1.8	3.4
11-17....	222.6	5.30	11.80	3.4	1.5	2.9
18-2'....	213.4	5.35	11.42	3.1	1.4	2.7
:5-31....	211.2	5.30	11.19	3.3	1.6	3.0
Apr. 1- 7....	211.1	5.25	11.08	2.7	1.3	2.5
8-14....	213.3	5.20	11.09	2.6	1.2	2.3
15-21....	206.1	5.20	10.72	2.5	1.2	2.3
22-28....	202.9	5.15	10.45	3.0	1.5	2.9
29-May 5	198.1	5.27	10.17	2.8	1.4	2.7
May 6-12....	197.9	5.20	10.29	2.8	1.4	2.7
13-19....	201.4	5.30	10.67	2.3	1.1	2.1
20-26....	222.6	5.38	11.98	2.4	1.1	2.1
27-June 2	227.8	5.20	11.85	4.0	1.8	3 4
June 3- 9....	220.1	5.25	11.56	3.4	1.4	2.7
10-16....	217.9	5.10	11.11	2.8	1.3	2.5
17-23....	208.8	5.03	10.51	3.6	1.7	3.2
24-30....	197.6	5.10	10.08	3.1	1.6	3.0
Total....	4778.4	.....	254.03	....	....	....

* Freshened June 23, 1906.
† Dec. 5 in heat.
‡ Change of attendant.
§ Dry Nov. 12, 1907. Hand milked for one week. Fresh Jan. 16, 1908. Put on machine Jan. 29.

TABLE XVIII.—WEEKLY PRODUCTION OF JESSIE DURING PERIOD OF MACHINE MILKING.

DATE.	Milk.	Fat.		STRIPPINGS	Per cent of total production	
	Lbs.	Per ct.	Lbs.	Lbs.	Milk.	Fat.
1907.						
May 8–14....	*143.4	5.60	8.07	3.0	2.1	5.0
15–21....	168.4	5.35	9.01	5.0	3.0	7.2
22–28....	181.1	5.70	10.32	2.0	1.1	2.6
29–June 4	159.2	6.00	9.55	1.9	1.2	2.9
June 5–11....	155.3	6.75	10.48	2.6	1.7	4.1
12–18....	176.2	5.33	9.39	1.9	1.1	2.6
19–25....	166.6	5.48	9.13	1.8	1.1	2.6
26–July 2	166.0	5.35	8.88	2.7	1.6	3.8
July 3– 9....	163.2	5.18	8.45	4.7	2.9	7.0
10–16....	151.7	5.30	8.04	7.0	4.6	11.0
17–23....	142.8	5.05	7.21	4.5	3.2	7.7
24–30....	140.5	5.25	7.38	6.6	4.7	11.3
31–Aug. 6	130.8	5.08	6.65	5.6	4.3	10.3
Aug. 7–13....	122.6	5.20	6.38	10.7	8.7	20.1
14–20....	126.3	5.23	6.61	8.5	6.8	16.3
21–27....	124.5	5.20	6.47	8.1	6.5	15.6
28–Sept. 3	119.5	5.28	6.31	9.2	7.8	18.7
Sept. 4–10....	124.3	5.30	6.59	9.7	7.8	18.7
11–17....	126.5	5.18	6.55	6.7	5.4	13.0
18–24....	115.2	5.38	6.20	7.8	6.8	16.3
25–Oct. 1	106.2	5.73	6.09	11.6	10.1	24.2
Oct. 2– 8....	108.2	5.40	5.84	8.0	7.4	17.8
9–15....	102.9	5.63	5.79	5.3	5.1	12.2
16–22....	95.6	5.90	5.64	4.4	4.6	11.0
23–29....	97.6	5.58	5.45	3.2	3.3	7.9
30–Nov. 5	89.8	5.85	5.25	5.5	6.2	14.9
Nov. 6–12....	†89.4	5.88	5.26	....	....	....
13–19....	9.12	5.60	5.16	4.2	4.6	11.0
20–26....	85.5	5.73	4.90	3.0	3.5	8.4
27–Dec. 3	85.3	5.80	4.95	4.0	4.7	11.3
Dec. 4–10....	83.2	5.73	4.77	3.8	4.6	11.0
11–17....	84.5	5.80	4.90	5.0	5.9	14.2
Dec. 18–24....	79.2	5.93	4.70	2.8	3.5	8.4
25–31....	79.8	5.88	4.69	2.0	2.5	6.0
1908.						
Jan. 1– 7....	78.2	5.93	4.64	1.8	2.3	5.5
8–14....	80.6	5.80	4.67	1.8	2.2	5.3
15–21....	79.5	5.73	4.56	1.4	1.8	4.3
22–28....	78.9	5.75	4.54	1.3	1.7	4.1
29–Feb. 4	77.2	5.85	4.52	1.8	2.3	5.5
Feb. 5–11....	74.7	5.85	4.37	1.8	2.4	5.8
2–18....	79.5	5.70	4.53	2.0	2.5	6.0
19–25....	78.5	5.80	4.55	1.6	2.0	4.8
26–Mar. 3	75.2	5.75	4.32	1.7	2.3	5.5
Mar. 4–10....	78.7	5.70	4.49	1.7	2.2	5.3
11–17....	78.6	5.70	4.48	1.7	2.2	5.3
18–24....	75.5	5.80	4.38	1.4	1.9	4.6
25–31....	77.3	6.00	4.64	1.1	1.4	3.4
Apr. 1– 7....	72.6	6.00	4.36	2.2	3.0	7.2
8–14....	73.8	5.95	4.39	2.0	2.7	6.5
15–21....	73.1	6.10	4.46	2.0	2.7	6.5
22–28....	72.1	5.93	4.28	2.3	3.2	7.7
29–May 5	71.3	6.24	4.35	2.6	3.6	8.6
6–12....	68.9	5.95	4.10	2.7	3.9	9.4
13–19....	50.7	7.40	3.75	3.2	6.3	15.1
20–26....	56.8	6.45	3.66	2.7	4.8	11.5
27–June 2	71.0	6.20	4.40	1.2	1.7	4.1
3– 9....	73.1	6.00	4.39	1.1	1.5	3.6
10–16....	75.6	6.10	4.61	1.1	1.5	3.6
17–23....	76.2	5.93	4.52	1.1	1.4	3.4
24–30....	68.2	6.00	4.09	1.4	2.1	5.0
Total....	5955.8	.....	337.04	....	....	....

*Put on machine May 9, 1907.
†Hand milked for a week.

TABLE XIX.—WEEKLY PRODUCTION OF PERCHANCE DURING PERIOD OF MACHINE MILKING.

Date.	Milk. Lbs.	Fat. Per ct.	Fat. Lbs.	Strippings. Lbs.	Strippings. Per cent of total production. Milk.	Strippings. Per cent of total production. Fat.
1906.						
Oct. 17-23...	170.5	4.11	7.01	*...	....	....
24-30...	164.1	4.32	7.10	....	....	....
31-Nov. 6	150.7	4.03	6.08	8.7	5.8	7.7
Nov. 7-13...	151.1	4.02	6.08	4.6	3.0	4.0
14-20...	142.1	4.20	5.97	8.4	5.9	7.7
21-27...	131.9	4.00	5.28	12.0	9.1	11.7
28-Dec 4	129.3	4.08	5.28	7.4	5.7	7.4
Dec. 5-11...	124.3	4.00	4.99	3.7	3.0	3.8
12-18...	123.5	4.30	5.31	4.1	3.3	4.3
19-25...	117.8	4.45	5.24	3.9	3.3	4.3
26-Jan. 1	111.5	4.40	4.91	3.0	2.7	3.5
1907.						
Jan. 2-8...	104.7	4.58	4.79	2.6	2.5	3.2
9-15...	108.9	4.43	4.82	2.8	2.6	3.3
16-22...	98.9	4.48	4.43	2.2	3.2	4.2
23-29...	93.3	4.80	4.48	2.8	3.0	4.0
30-Feb. 5	86.2	4.83	4.16	2.7	3.1	4.1
Feb. 6-12...	86.9	4.58	3.98	2.8	3.2	4.2
13-19...	88.7	4.38	3.89	2.5	2.8	3.7
20-26...	83.9	4.33	3.63	2.9	3.5	4.5
27-Mar. 5	80.2	4.43	3.55	2.7	3.4	4.4
Mar. 6-12...	78.9	4.53	3.57	2.5	3.2	4.1
13-19...	79.0	4.33	3.42	2.9	3.7	4.8
20-26...	76.5	4.30	3.29	2.8	3.7	4.8
27-Apr. 2	77.2	4.23	3.27	2.8	3.6	4.7
April 3-9...	66.8	4.50	3.01	3.6	5.4	7.0
10-16...	58.4	4.43	2.59	2.9	5.0	6.4
17-23...	61.2	4.53	2.77	3.0	4.9	6.4
24-30...	60.4	4.50	2.72	2.8	4.0	5.8
May 1-7...	65.4	4.33	2.83	2.9	4.4	5.7
8-14...	66.9	4.38	2.93	2.7	4.0	5.2
15-21...	61.2	4.75	2.91	3.3	5.4	7.0
22-28...	64.2	4.85	3.11	2.8	4.4	5.7
29-June 4	77.3	4.60	3.56	†...	....	....

Date.	Milk. Lbs.	Fat. Per ct.	Fat. Lbs.	Strippings. Lbs.	Strippings. Per cent of total production. Milk.	Strippings. Per cent of total production. Fat.
1907.						
Dec. 4-10...	191.5	4.20	8.04	‡	...	....
11-17...	195.4	4.18	8.17	‡	....	....
18-24...	213.4	4.38	9.35	5.5	2.6	4.9
25-31...	213.6	4.48	9.57	5.5	2.6	4.9
1908.						
Jan. 1-7...	210.7	4.38	9.23	4.2	2.0	3.8
8-14...	215.5	4.45	9.59	4.6	2.1	4.0
15-21...	213.5	4.20	8.97	4.0	1.9	3.6
22-28...	212.3	4.25	9.02	3.8	1.8	3.4
29-Feb. 4	209.8	4.40	9.23	4.0	1.9	3.6
Feb. 5-11...	205.7	4.35	8.90	4.7	2.3	4.4
12-18...	201.8	4.30	8.68	4.2	2.1	4.0
19-25...	201.9	4.30	8.68	5.3	2.6	4.9
26-Mar. 3	195.4	4.35	8.50	5.6	2.9	5.5
Mar. 4-10...	192.9	4.40	8.49	4.7	2.4	4.6
11-17...	180.2	4.35	7.84	4.6	2.6	4.9
18-24...	172.0	4.45	7.65	4.3	2.5	4.8
25-31...	176.5	4.60	8.12	3.7	2.1	4.0
April 1-7...	183.0	4.35	7.96	4.1	2.2	4.2
8-14...	189.3	4.40	8.33	2.7	1.4	2.7
15-21...	180.5	4.45	8.03	3.3	1.8	3.4
22-28...	186.7	4.25	7.93	3.7	2.0	3.8
29-May 5	185.3	4.28	7.93	3.6	1.9	3.6
May 6-12...	182.6	4.55	8.31	2.9	1.6	3.0
13-19...	193.4	4.40	8.51	3.0	1.5	2.9
20-26...	216.8	4.50	9.76	2.8	1.3	2.5
27-June 2	222.8	4.55	10.14	3.2	1.4	2.7
June 3-9...	224.7	4.25	9.55	2.9	1.3	2.5
10-16...	221.8	4.30	9.54	3.1	1.4	2.7
17-23...	212.9	4.29	9.14	4.4	2.1	4.0
24-30...	205.0	4.35	8.92	4.2	2.0	3.8
Total....	5620.0	.....	245.87	....	....	....

*Freshened Sept. 18, 1906.
†Taken to Hill Farm, June 4, 1907. Milked by hand.
‡Fresh Nov. 30, 1907. Milked by hand. Put on machine Dec. 18, 1907.

TABLE XX.—PRODUCTION OF MACHINE MILKED COWS DURING EARLIER YEARS WHEN THEY WERE MILKED BY HAND (see p. 77)

NAME OF COW.	Period beginning.	Days from calving.	Number of weeks.	FIRST WEEK.		LAST WEEK.		AVERAGE DECREASE PER WEEK.		TOTAL PRODUCTION.		AVERAGE WEEKLY PRODUCTION.	
				Milk.	Butter fat.	Milk.	Butter fat.	Milk.	Butter fat.	Milk.	Butter fat.	Milk.	Butter fat.
				Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Laura...............	Jan. 28, 1903 Jan. 27 1904 Apr. 12, 1905	185 185 190	20 20 20	128.6 116.7 117.6	6.69 5.84 6.23	112.9 98.8 105.2	5.98 5.14 4.95	.8 .9 .7	.04 .04 .07	2302.7 2020.7 2374.4	125.30 105.00 117.73	115.1 101.0 118.7	6.27 5.25 5.89
Average.......	....	**187**	**20**	**121.0**	**6.25**	**105.6**	**5.36**	**.8**	**.05**	**2232.6**	**116.01**	**111.6**	**5.80**
Laura...............	Aug. 13, 1902 July 29, 1903 Oct. 12, 1904	7 3 9	14 14 14	147.7 100.7 190.4	6.50 [illegible].23 9.52	157.8 138.7 171.4	7.89 6.66 8.74	+.8 +3.0 1.5	+.11 +.19 .06	2502.5 2301.5 2772.2	124.09 113.19 143.67	178.8 164.4 198.1	8.86 8.09 10.26
Average	....	**6**	**14**	**146.3**	**6.75**	**156.0**	**7.76**	**+.7**	**+.08**	**2525.4**	**126.98**	**180.4**	**9.07**
Perchance..........	Oct. 12, 1904 Nov. 8, 1905	41 43	30 30	154.8 [illegible]01.2	6.50 8.25	109.5 134.0	5.04 6.16	1.6 2.3	.05 .07	4026.4 4722.5	185.10 [illegible]09.40	134.2 157.4	6.17 6.98
Average... ..	....	**42**	**30**	**178.0**	**7.38**	**121.8**	**5.60**	**1.9**	**.06**	**4374.5**	**197.25**	**145.8**	**6.58**
Perchance..........	Oct. 11, 1905	15	28	198.6	8.34	135.0	5.94	2.4	.09	4843.1	210.11	173.0	7.5
Just in Time........	Aug. 9, 1905	52	33	142.4	6.12	76.9	4.15	2.0	.06	3720.9	184.51	112.8	5.59
Just in Time...	Oct. 11, 1905	115	31	127.8	6.01	58.2	3.78	2.3	.07	2844.9	149.63	91.8	4.83
Broadway......... ..	Mar. 22, 1905	25	33	137.2	8.37	103.6	6.24	1.1	.07	3764.0	218.47	150.6	8.74
Macella.............	Oct. 5, 1904 Oct. 18, 1905 Oct. 24, 1906	24 24 21	33 33 33	164.0 275.9 187.0	9.68 13.93 9.63	103.0 169.8 142.1	6.49 11.04 8.67	1.9 3.3 1.4	.10 .09 .03	4237.6 6600.3 4866.0	256.22 383.85 286.48	128.4 200.0 147.5	7.76 11.63 8.68
Average........	....	**23**	**33**	**209.0**	**11.08**	**138.3**	**8.73**	**2.2**	**.07**	**5234.6**	**308.85**	**158.6**	**9.36**

Dorine	May 21, 1902	128	30	152.1	8.06	70.1	4.49	2.8	.12	3661.1	199.80	122.0	6.66
	July 22, 1903	132	30	131.0	6.29	55.1	3.41	2.6	.10	2582.3	144 42	86.1	4.81
	Aug. 10, 1904	132	30	133.9	7.23	79.4	4.68	1.9	.09	3157.9	175.25	105.3	5.84
	Oct. 4, 1905	128	30	155.4	7.93	87.4	5.16	2.3	.10	3420.0	192.64	114.0	6.42
Average	...	**130**	**30**	**143.1**	**7.38**	**73.0**	**4.44**	**2.4**	**.10**	**3205.3**	**178.03**	**106.9**	**5.93**
Dorine	Jan. 29, 1902	16	22	182.5	10.22	151.3	7.72	1.5	.12	3401.4	184.84	154.6	8.40
	Mar. 25, 1903	13	22	182.1	9.11	116.4	5.69	3.1	.16	3326.7	164.67	151.2	7.49
	Apr. 13, 1904	13	22	183.1	11.72	133.1	7.45	2.4	.20	4074.3	218.37	185.2	9.93
	June 14, 1905	16	22	268.9	12.91	125.8	6.92	6.8	.28	4124.1	201.80	187.5	9.17
Average	...	**15**	**22**	**204.2**	**10.99**	**131.7**	**6.95**	**3.5**	**.19**	**3731.6**	**192.42**	**169.6**	**8.75**
Queen	Mar. 14, 1906	35	33	207.4	10.58	127.6	6.95	2.5	.11	5279.1	260.51	160.0	7.89
Josephine	Mar. 16, 1904	179	28	213.7	7.48	140.5	5.62	2.7	.07	5063.4	171.56	180.8	6.13
Maggie	May 27, 1903	69	43	314.7	10.07	185.2	6.11	3.1	.09	10132.9	334.85	235.6	7.79
Maggie	Apr. 1, 1903	13	28	286.2	11.59	250.9	7.53	1.3	.15	7712.2	260.42	275.4	9.30
	Sept. 14, 1904	14	28	306.4	12.26	205.1	6.77	3.8	.20	7236.3	245.76	258.4	8.78
	Oct. 25, 1905	17	28	374.0	14.59	230[illegible]	8.08	5.3	.24	9458.9	322.82	337.8	11.53
Average	...	**15**	**28**	**322.0**	**12.81**	**2[illegible].9**	**7.46**	**3.5**	**.20**	**8135.8**	**276.33**	**290.5**	**9.87**
Cozie	Jan. 27, 1904	42	4	173.6	9.72	158.9	9.06	4.9	.22	652.2	36.57	161.3	9.09
	Jan. 18, 1905	39	4	150.2	7.36	136.3	6.54	4.6	.27	582.6	28.71	145.7	7.18
	Apr. 25, 1906	39	4	217.1	11.51	188.5	10.37	9.5	.38	835.3	45.08	208.8	11.27
Average	...	**40**	**4**	**180.3**	**9.53**	**161.2**	**8.66**	**6.3**	**.29**	**690.0**	**36.72**	**172.5[illegible]**	**9.18**

Wisconsin Dairy Farmers Reporting Their Experiences With the B. L. K. Milking-Machine.

Name and County.	Name and County.	Name and County.	Name and County.
Allen, J. G., Walworth.	Butters, E. E., Sheboygan.	Legler, L. G., Green.	Nutricia Farm, Ozaukee.
Babler, John N., Green.	Daetz, Fred, Sheboygan.	Leicht, Jacob, Washington.	Pollock Bros., Jefferson.
Bates, G. W., Sheboygan.	Davis, Dallas E., Green.	Maul, John, Jefferson.	Shadewald, Frank, Iowa.
Behnke, Arthur, Dane.	Gilberts, Irwing, Walworth.	Maul, Wm., Jefferson.	Siemers, A. W., Sheboygan.
Bemis, C. F., Sheboygan.	Granzow, Frank A., Walworth.	McCanna, C. B., Racine.	Stearns, C. K., Racine.
Besteder, Wm., Walworth.	Harter, Andrew, Richland.	Mitchell, J. J., H. E. Cocroft, Mgr., Walworth.	Scribner, F. H., Fond du Lac.
Bingham, Walter, Walworth.	Hemstreet, Fred, Walworth.	Nordman, E., Langlade.	Stoney, C. L., Rock.
Burchard, Ed., Racine.	Kuhlney, Wm., Sheboygan.		

Table XXI.—First Reports of Wisconsin Dairy Farmers using the B. L. K. Cow Milker.[1]

Herd number.	When installed.	Experience.	Number of cows milked by machine.	Breed.	Number of men employed for milking. At time of report.	Number of men employed for milking. Previously.	Number of machines (pails) used.	Number of sets mouth-pieces and teat-cups used.	Time required for Preparation.	Time required for Milking.	Time required for Cleaning.
		months.							minutes.	minutes.	minutes.
1	Aug. 22, 1906	9	32	Holstein	1	3	3	5	....	60	20
2	Nov. 1, 1906	7	44	Jersey	2	4	3	3	....	90	10
3	Nov. 1, 1906	7	18	Holstein	1	2	2	5	....	....	10
4	Dec. 1, 1906	6	26-28	Common & mixed	1	2 or 3	3	7	....	60	15
5	Jan. 20, 1907	5	30	Holstein	2	3	4	4	....	45	20
6	March 1, 1907	3	22	Holstein	1	3	2	6	....	60	15
7	March 2, 1907	3	20	Holstein	1	3	3	8	....	45*	15
8	March 8, 1907	3	31	Holstein	1	4	2	7	....	90	10
9	Mar. 23, 1907	2	25	Jersey††	1	3	2	8	....	105	15
10	April, 1907	2	40	Mixed	2	4	4	12	....	85	10§
11	April 1, 1907	2	24	Red Polled	1	4	3	6	....	5	20
12	April 23, 1907	1	50	Holstein††	3	4‡	4	12	....	75	15
13	May 18, 1907	1	24	Holstein & Shorth.	1	2	2	6	....	85	15
14	May 10, 1907	1	21	Holstein	1	2	3	9	....	60	10
15	May 11, 1907	1	60	Mixed	2	3	4	8	....	100	30

[1]Supplementary reports from dairy herds No. 1—15 and No. 23 are given on pp. 147-8.
*Attendant weighs each cow's milk separately. ‡Calves fed after milking. §Two men. ††Pure breds.

TABLE XXI.—FIRST REPORTS OF WISCONSIN DAIRY FARMERS USING THE B. L. K. COW MILKER—Continued.

Herd number.	When installed.	Experience.	Number of cows milked by machine.	Breed.	Number of men employed for milking.		Number of machines (pails) used.	Number of sets mouth-pieces and teat-cups used.	Time required for		
					At time of report.	Previously.			Preparation.	Milking.	Cleaning.
									minutes.	minutes.	minutes.
16	April 15, 1907	16	28	Gr. Jersey & Holste'n	1	2	2	6	10	90–105	10–15
17	July 26, 1907	12	18–20	Jerseys††	1	3	2	4	15	45	30
18	Dec., 1907	7	35	Holstein	1 or 2	3½	3	14	10–15	60	15
19	June 26, 1907	13	18	Gr. Holstein & Durh.	1	2	2	6	5	50–60	5
20	....	....	28	Mixed	1	2	2	4	5	60	10
21	June 27, 1907	13	24	Natives & Gr. Holst.	1½	3	2	6	5	80	10–15
22	May 30, 1908	2	20	Durham	1	2	2	5	5	60	10
23	May 20, 1908	2	24	Gr. Guernsey	2	2	4	12	5	60–75	3
24	July 10, 1908	1	18–22	Gr. Holstein	2	2 to 4	2	4–6	3–5	50–60	10–15
25	April, 1907	16	65	Mixed	2–3	6	6	....	30	75–90	180†
26	July 1, 1908	2	50	Holstein and Jersey	2	4–5	4	12	15	90	20
27	May 20, 1907	16	25	Gr. Holstein	1	2	2	7	10	90	5–10
28	May, 1997	16	44	Holstein & common.	1	3	3	9	15	90	10
29	Apr. 22, 1907	17	45	Mixed	2	3	3	9	5	110	20
30	Nov., 1907	10	40	Mixed	2	4	4	12	2–5	90	10–15
31	July 11, 1907	14	20	Gr. Durham	1	2–3	2	6	10	50	10
32	July 4, 1907	8	30	Grades	2	3	2	6	5	60	5
33	July 1, 1907	13**	15	Mixed	2	2	2	5	10	45	10
34	June 15, 1908	3	14–20	Mixed	1	3	2	7	5	30–40	15
35	May 1, 1907	17	50	Mixed	3	4–5	4	19	10	90	15
36	Aug 1, 1906	26	50	Mixed	2	5	5	14	10	100	20
37	June, 1908	3	20	Mixed	2	2	2	6	5–10	60–75	15
38	Nov., 1907	10	35	Holstein	2	2–3	3	8	5	45	8
39	June, 1908	3	35	Mixed	2	3	2	7	5	90	5
40	June, 1907	15	26	Holstein and mixed.	2	3	2	6	10	60	10
41	Mar. 23, 1908	6	42	Holstein	2	3	4	....	10	50	15

††Pure breds. †Error. **Machine not used in winter time.

TABLE XXI.—FIRST REPORTS OF WISCONSIN DAIRY FARMERS USING THE B. L. K. COW MILKER—Continued.

Herd number.	Are machine-milked cows stripped?	Weight of strippings per ten cows.	Do you consider it necessary to strip cows.	Difficulty in operating machine with any cows.	Power used.	Average cost of power per month.	Have any parts of milking machine shown weakness?
		Lbs.					
1....	Yes, in the teat-cups.	1	Yes, to be sure they are milked dry.	No....	3 H. P. gasoline en-engine.	$3.00,—and pumps water for stock.	No.
2....	Yes..............	3	No......................	No......................	3½ H. P. gasoline engine.	12 00	Escapement springs.
3....	Some are.........	½	Some of the cows do not always milk out c ean	At first, in getting them to give down their milk	Tread power. Two light horses.	....	Mouth-pieces. Escapement springs.
4....	Yes..............	2 to 4	To know that the work is done well. If fixtures do not exactly fit, the c w may not always milk out clean.	No......................	2 H. P. gasoline engine.	1 0	No.
5....	No...............	....	Not if teat-cups fit properly.	With one cow...........	Electricity..........	....	No.
6....	Yes..............	About 2	Yes.....................	No......	Gasoline engine.....	3 00	No.
7....	Yes, into teat-cups.	Practically none if machine is given time.	Yes, for if cows have garget those teats will not milk.	No, cows that we were compelled to tie when teats were sore, now pay no attention to milking.	3 H. P. gasoline engine.	3 60 to 4 50	Escapement springs, two sets.
8....	Some are.........	Varies.	Yes, but only for hard milkers.	No......................	2 H. P. gasoline engine.	1 50 to 2 00	No.
9....	Some are.........	½	There may be some cases but not majority	No.....	2 H. P. gasoline engine.	9 90	No

10....	Yes..............	1	Yes......................	No.....	2 H. P. gasoline engine.	2 40	Skirts on mouth pieces.
11....	Yes..............	2	Yes......................	No.......................	Two-horse tread power, or 6 H. P. gasoline.	6 00	No.
12....	Yes..............	6-10	The o der ones..........	Only a few..............	3½ H. P. gasoline engine or ejector.	....	No.
13....	Yes..............	1	Only where quarters do not milk out evenly.	No. Can milk cows that are very difficult to milk by hand.	2 H. P. gas engire...	2 00	No.
14....	Yes..............	½	Have not used long enough to say.	No.......................	2 H. P. gasoline engine.	1 25	No.
15....	Yes..............	4	Yes, as occasionally a cow will hold her milk and seem to be dry.	No.......................	5 H. P. gasoline engine.	9 00	No.
16....	Yes..............	2 to 4	Yes, because cows do not give milk on 4 teats alike.	No. One young Jersey was very nervous but broke in soon.	2½ H. P. gasoline engine.	2 50	No.
17....	Yes..............	½	To be satisfied they are milked dry.	No..............	Electricity..........	3 00	No.
18....	Yes...	2 to 3	Some cows retain a little which can be detected only in this way.	Have had two cows that I never could milk well.	Gas engine..........	4 00	Some of the new tubes are too thin.
19....	Yes..............	1	Sometimes milk in one quarter and not others	Not after they got used to it.	Gasoline engine.....	3 00	No.
20....	Yes..............	2	It certainly is...	No.......................	Gasoline............	....	No.
21....	Yes..............	2 to 4	Yes, especially on the old cows.	With one old cow. Not serious.	2 H. P. gasoline engine.	2 00	No.
22....	No...............	....	No......................	No.......................	2 H. P. gasoline engine.	2 50	No.
23...	Yes..............	1 to 12	Yes, some cows will not give all their milk to the machine.	One was afraid and kicked badly at first but is all right now.	2½ H. P. gasoline engine.	10 50	No.

TABLE XXI.—FIRST REPORTS OF WISCONSIN DAIRY FARMERS USING THE B. L. K. COW MILKER—Continued.

Herd number.	Are machine-milked cows stripped?	Weight of strippings per ten cows.	Do you consider it necessary to strip cows?	Difficulty in operating machine with any cows.	Power used.	Average cost of power per month.	Have any parts of milking machine shown weakness?
		Lbs.					
24....	Yes..............	2	Sometimes a cow will seem clean but will give milk when milked by hand.	No.......................	Gasoline engine.....	$1 75	No.
25....	Yes..............	Very little	Yes, it insures better results.	Very seldom. Usually over come in time.	15 H. P. gasoline engine or steam ejector.	....	No.
2'....	Yes..............	3 to 5	Yes......................	One cow with large teats.	2½ H. P. gasoline engine.	9 00	Only springs.
27....	Yes..............	2 to 3	Yes, occasionally a cow will not milk clean.	No.......................	Gasoline engine......	....	No.
28....	Yes..............	2 to 3	Always. Does milk all cows clean.	Yes. Some do not give down all their milk.	Gasoline engine.....	4 50	No.
29....	Yes..............	2 to 3	Yes......................	Occasionally, a little....	2 H. P. gasoline engine.	2 50	No.
30....	Yes..............	2	Yes...	No.......................	Gasoline engine......	3 00	No.
31....	Yes..............	8	Yes......................	No	2 H. P. gasoline engine.	1 50	No.
32....	Yes...	....	Some cows..............	No........	Gas engine	1 75	No.
33....	Milk out into a pail.	....	Yes, very necessary ...	With one on high (16) vacuum, and 5 on low (15).	2½ H. P. gasoline....	1.50 m.m. only..	Only mouth-pieces. Couple gave out.
34....	Yes, to make sure...........	Less than qt.	Yes......................	No.......................	2 H. P. gasoline.....	Run about 2 hrs.	Nothing but m.p. Bot. 2.

35....	Yes. That's business. Do it right.	Couple of lbs.	Yes....................	Not much, hardly worth mentioning.	2 H. P. gasoline......	30 gals. Milking only.	No. M. P.'s, 1 dozen. Few springs. ½ sup. curtains
36....	Yes.............	3 lbs.	To see whether cows are milked.	No......................	5 H. P. gasoline, old.	½-¾ gal. a milking	M. P. (2 years) 15-18 a year.
37....	Yes.............	2-3 lbs.	On some cows..........	No, cows all took to it kindly and seem to give down readily.	2½ H. P. gasoline....	15-18 gals. a mo., estimated.	No. One M.P.
38....	Yes.............	....	Heifers only to save time. Old cows, yes.	Only one, this one particular by h. m. O. K. now.	2 H. P. gasoline......	13 gals. a month, 14-184.	No, only rubber hose.
39....	Yes.............	Less than 2.	Do not know as it is.	A few on the start. O.K. now.	2 H. P. gasoline.....	20 gals. at 15-20c.	Only rubber parts. Got 1 set springs.
40....	Yes.............	Varies.	Yes....................	No......................	Tread power.........	....	No.
41....	Yes.............	1 lb. or more.	Yes, sometimes some milk may be left.	No. Cows seem to like the machine better than hand.	Gasoline engine.....	$4.50	Some.

NOTES ON COST OF POWER PER MONTH: 1.—Pumps water for stock while milking. 4.—Also runs separator. 8 and 19.—Run separator and pump water at same time. 21.—Also pumps water for 30 head of cattle and horses. 23.—Also runs separator and grindstone. 26.—Also runs separator. Total time about two hours per milking. 34 and 38.—Also pumps water.

TABLE XXII.—DETAILS OF FIRST REPORTS OF WISCONSIN

Herd No.	Have you noticed any difference in the effiency of the machine with old or with young cows, with fresh cows, or such advanced in their lactation.	How does the yield now obtained compare with what you have had at this time in earlier years under hand milking?	What disposition do you make of your milk.	Have you had any difficulty in running the machine so far.
1....	No......................	I don't notice any difference.	Cheese factory.	No... ....
2....	Machine works best on young cows. My cows were all fresh except two and I milked those with in five weeks of lactation.	Just about the same..	Make butter...	No.............
3....	No......................	While some of the cows are doing fully as well, others do not seem to be.	Cheese factory.	At first.........
4....	No......................	This is a difficult matter to determine. But I cannot say that I have seen any difference one way or the other.	Cream retailed	No. The great objection we have found so far is the accumulation of filth in the vacu'm pipes, which must be ke t clean in some manner.
5....	Young cows seem to milk better than old cows.	No way of telling.....	Condensed fattory.	No.............
6....	No......................	I do not receive as much milk this year as previous but I think it is due to feed.	Cheese Factory	The machine is out of adjustment at times.
7....	No......................	The first few days cows held their milk but after being accustomed to machine the amount of milk secured averaged a little more than by hand milking.............	Butter..........	No.............
8....	No...........	About the same......	Sell cream.....	No.............

DAIRY FARMERS USING THE B. L. K. COW MILKER.

Have you or your customers noticed any difference in the machine milk and that drawn by hand, as to flavor, keeping quality, or the quality of products made therefrom.	What saving is there in your opinion in using the machine in herds with less or more than 30 cows?	What are your views at present as to the practicability and economy of the B. L. K. milking machine under your conditions of dairying.
No..................	A 40 per cent saving of labor in a herd of 30 cows, more in larger herds.	Practical because it does the work. Economical because it does it better and cheaper than you can hire it done by hand.
My opinion is that machine -drawn milk is best.	A saving of time in that it takes no longer to get ready to milk 30 cows than it does less.	For me it is both practical and economical.
As my milk is the only machine-drawn milk in factory the result would hardly be noticeable.		Cannot say at present whether it is or is not a practical investment with so small a herd.
No. We think the cream keeps fully as well, if not better, but of course we have had no real trying weather as yet.	If one could always have real good help I think the saving would not be a very great matter unless a man had so many cows that he had to keep help just for the purpose of milking but it is a consolation to know that you can milk your own cows if you have to do so, and I think it is easier to secure hired help if they don't have to milk.	I believe the machines are practicable, but as to the economy, past an out lay of $500 in a herd of 30 cows is a question for each man to decide for himself. It is nevertheless a consolation to me to know that I am not obliged to get down every night and morning and milk 10 cows and especially since one hand has been crippled with rheumatism.
No....	Saves the labor of one man in herd of 34 cows.	Have not used the machine long enough to justify an answer.
The milk is cleaner........	4 hours labor per day, because one man does the milking.	Cannot state................
Nothing that can be traced to the milking machine. Milk is cleaner. Practically no sediment on strainer cloth. Had some trouble with flavor of petroleum from fumes escaping from engine: remedied now.	It used to take the men 45-60 minutes to milk and care for milk that one man handles in less time now and in a larger herd more time can be saved: but with a herd of 20, the cost of machine is but little less than by old method.	I would not go back to old method if machine keeps up the records made with me thus far. I entend to increase my herd to 60 head of milkers and use six milk pails.
No.......	It nearly saves a man......	It makes dairying easier.

TABLE XXII.—DETAILS OF FIRST REPORTS OF WISCONSIN

Herd No.	Have you noticed any difference in the efficiency of the machine with old or with young cows, with fresh cows, or such advanced in their lactation.	How does the yield now obtained compare with what you have had at this time in earlier years under hand milking.	What disposition do you make of your milk.	Have you had any difficulty in running the machine so far.
9....	With fresh cows while the udder is a little thick, it is harder to empty out than cows farther along in lactation.	I don't think there is much difference.	Cream goes to city.	None whatever
10....	Yes; new milkers and young ones preferable.	I think better than the average milker we can employ.	Sell it to a butter and cheese Co.	No....... ......
11....	Yes; young cows are more readily milked.	About the same	Take it to cheese factory and separate some.	No.............
12....	Cows that came in last fall do not milk as well as fresh cows. It takes more manipulation.	Cannot see any difference. At first they fell on the flow of milk, but when accustomed they came back to old flow.	Butter	Little..........
13....	No; only with strippers that milk easy and let their milk right down. It should not be left on too long.	I think that under the same conditions they are better.	Co-operative creamery.	No.............
14....	Young cows and fresh cows give their milk down more readily.	About the same,......	Creamery......	A little.........
15....	I do think it has a tendency to dry cows quicker, that are advanced, than by hand milking.	Not so good...........	Condensery....	No.............

DAIRY FARMERS USING THE B. L. K. COW MILKER.

Have you or your customers noticed any difference in the machine milk and that drawn by hand, as to flavor, keeping quality or the quality of products made therefrom.	What saving is there in your opinion in using the machine in herds with less or more than 30 cows.	What are your views at present as to the practicability and economy of the B. L. K. milking machine under your condition of dairying.
We have had no complaint or comments, but we feel sure the quality has improved thro the improved sanitary conditions.	We calculate we can save one man, which means about $450 a year or the price of our outfit.	Our experience is too limited to give definite opinion.
Yes, better................	It saves me two milkers....	It is preferable to the ordinary hand milker, if the cows hold to their regular flow as well as at the present time.
No........................	It takes the place of one extra man.	Saves time and labor and run with less cost.
In family use we can see a change in the flavor and that the milk keeps sweet longer.	In less than 30 cows I think they would be hardly practical. In large herds I think they are the best thing ever put bef re the dairy man.	This machine is now saving me one man, and his wages would be at least $30 per month, and his board and keep at least $15 more. Another thing, men can be more easily gotten on a dairy farm and they are not so independent, while a man who can use a team and do farm work would be no good in many cases to milk. In this way the dairyman can use help le s used to dairy work. But for the milkers it takes more care and watching to do the work well than by hand milking.
I think that the milk is much cleaner and it wi l test more than when milked by hand.	It gives one of us time to do other chores and as soon as the cows are milked we are ready to move to our day's work.	Very satisfactory so far.
No........................	Saving of time. Increasing test.	
No; only when rubber parts were kept in brine. (Aug., 1907, inspector at condensery said milk was running bad and "off flavor.")	I don't think there is any, if you can get good hand milkers.	A little doubtful.

TABLE XXII.—DETAILS OF FIRST REPORTS OF WISCONSIN

Herd No.	Have you noticed any difference in the efficiency of the machine with old or with young cows, with fresh cows, or such advanced in their lactation.	How does the yield now obtained compare with what you have had at this time in earlier years under hand milking.	What disposition do you make of your milk.	Have you had any difficulty in running the machine so far.
16....	Took longer with cows advanced in lactation and cows where the calf was taken off, but by manipulating the bags they soon gave their milk down.	The cows held out better than by hand milking.	Cheese factory.	No..............
17....	No......................	Getting more milk. Cows harder to get dry before freshening.	Sell butter and cream.	No..............
18....	I find that machine broken heifers are best. There are some cows that milk better when first fresh.	Very favorably.......	Condensery....	No..............
19....	I think young cows, especially heifers, will do better than old cows.	I get fully as much...	Sell my cream and make butter.	No..............
20....	No......................	Same..................	Condense......	No..............
21....	Young cows and cows lately fresh, milk more readily. Have had absolutely no bother with young heifers never milked by hand.	It is very much larger. We are obtaining the best yield we have ever had in at least 13 years.	Cheese factory	No; except from pails overflowing and filling pipes.
22....	Very little difference.	About the same.......	Swiss cheese factory.	Not any........

DAIRY FARMERS USING THE B.-L. K. COW MILKER.

Have you or your customers noticed any difference in the machine milk and that drawn by hand, as to flavor, keeping quality or the quality of products made therefrom.	What saving is there in your opinion in using the machine in herds with less or more than 30 cows.	What are your views at present as to the practicability and economy of the B.-L. K. milking machine under your conditions of dairying.
Milk is cleaner than by hand-milking, provided machine is kept clean.	It pays any farmer to milk with machine from 15 cows up.	The machine paid for itself the first year. A man that has to milk 14 cows twice daily, wants from $35-$40 per month. Board and washing is worth from $12-$15 per month, and for 8 months, at $50 per month is $400; besides the fret you are always in, especially Sundays that they are there at milking time. I can recommend the machine, if handled right.
No	It saves us the wages of two men, which is $95 per month.	It is very practicable and much cleaner.
No	I think from 15 to 50 per cent in time may be saved.	I am not prepared to say.
I can't say that I have....	In a herd of 20-30 cows, you save the price of one man.	I think if managed right, they are a practical machine and with labor as it has been, I can hire cheaper and easier than before.
....	One man's time milking.	I think it is very much so.
No; only that it is cleaner.	The labor of at least 1 man. The saving would increase with increase in size of herd.	It is all right provided the dairyman can operate the machine himself or has a reliable man to do so. It is *not* a machine for a careless man to handle. It will do the work provided it is used as directed. We will be able to keep more cows, because we will not have to depend so much upon hired help.
No	Time and hard labor.	Yes, I think the machine milker is practical, for instance, if your hired help gets locked up over night, as mine did this week.

TABLE XXII.—DETAILS OF FIRST REPORTS OF WISCONSIN

Herd No.	Have you noticed any difference in the efficiency of the machine with old or with young cows, with fresh cows, or such advanced in their lactation.	How does the yield now obtained compare with what you have had at this time in earlier years under hand milking?	What disposition do you make of your milk.	Have you had any difficulty in running the machine so far.
23....	No, my cows all were new milkers before I got the machine from Dec. to May except one which dropped a calf this summer.	It is smaller, I am not satisfied with the results. I am going to milk by hand for a week, then with the machine for a week and weigh each milking. If you care to have my report I will send a correct account to you.	I send cream to the creamery.	No..............
24 ...	We think it is best to use it on heifers and find it works at its best on fresh cows. At present time, Aug. 5th, we are having trouble with some cows holding up their milk which gave us no trouble at all in June on full flow.	We think we get a better yield. The cows milk longer.	Creamery......	Nothing but with engines; they sometimes bother to beat the devil.
25....	No......................	It is just as good.	Made into nursing milk (Prof. Backbaus' process).	Not if the men do the work intelligently and as instructed.
26....	Haven't noticed any difference.	Slightly elow last year, but think pasture was better last year.	Sell cream to creamery.	No..............
27....	Heifers milk quicker and cleaner; as cows advance in lactation udder must be more manipulated.	No particular difference.	Creamery......	No..............
28....	Heifers milk well and all free and easy milkers, hard milkers take longer.	....	Sold in town and balance to creamery.	No..............
29....	Fresh cows milk best; no experience with young cows.	About as good results with machine.	Creamery......	No..............
30....	No particular difference.	Same..................	Creamery......	No.. ....

DAIRY FARMERS USING THE B. L. K. COW MILKER—Continued.

Have you or your customers noticed any difference in the machine milk and that drawn by hand, as to flavor, keeping quality, or the quality of products made therefrom.	What saving is there in your opinion in using the machine in herds with less or more than 30 cows?	What are your views at present as to the practicability and economy of the B. L. K. milking machine under your conditions of dairying.
No	I cannot tell until I have weighed the hand milked and machine milked for a week.	I am afraid the cows are going dry too fast. Monday morning I will milk by hand for a week, then with the machine for a week, then I can give you a better answer to this question if you want it.
The milk is far cleaner than any hand milking.	A big saving when your hired man tells you he is going to go.	The cows are milked the same every day and we believe will give more milk and if used per directions will not spoil or hurt any cow and then if your hired help leaves you to milk alone you can do it all right.
No; except that the milk has absolutely no cowy odor.	Saving in manual labor; but the power cost may over-ride this.	I would prefer to have my herd milked by machine and I place more confidence in it than in the general milker. We do not find that cows dry up quicker either.
No; slightly in favor of machine.	1-2 men	In the hands of a careful man the work is satisfactory.
No complaint from buttermaker.	Save 1 man under 30 cows in my case.	Satisfactory, run machine myself.
No complaints.	Would not use a machine in a he d less than 30 cows.	Good for a fresh flow of milk; not g od in dry season.
No	Save one man; one man can milk 30 cows alone.	It pays when milking over 20 cows and will continue to use it as long as I milk over 20 cows.
No	Saves one milker.	No fault to find.

TABLE XXII.—DETAILS OF FIRST REPORTS OF WISCONSIN

Herd No.	Have you noticed any difference in the efficiency of the machine with old or with young cows, with fresh cows, or such advanced in their lactation.	How does the yield now obtained compare with what you have had at this time in earlier years under hand milking?	What disposition do you make of your milk?	Have you had any difficulty in running the machine so far?
31....	Machine does not milk quite as well when cows start to dry off.	As good now as before.	Creamery......	No.............
32....	No........	No difference.........	Condensery....	No.............
33....	Best with fresh cows. A little more trouble starting old cows.	About the same from most cows. Five did not do well. One hand milked always. Ten milked right along by machine.	Retailed in city from cans.	A little in regulating escapement. Did not stay regulated. Told agent and he fixed it. Next milking running at nearly 100.
34....	Older cows are more affected by change from hand milking. No trouble, however.	It is not less. No record kept.	Sell in city.....	No.............
35....	No, same as by hand..	Figure yield is better. No records kept.	Condensery....	None, only engine.
36....	No. A stripper is a stripper, no matter how milked.	Don't see any difference. If I did would take it out.	Condensery....	No.............
37....	New milkers seem to milk the best, same as they would by hand.	Hard to tell. Pasture dried up this year and feed different. Think they are doing just as well considering this.	Ship milk to city.	No, never bothered us any.
38....	Heifers and fresh cows milk out best.	Not as large yield as in other years but same is true of neighbors, milk who by hand.	Cheese.........	No, not a bit...

Dairy Farmers Using the B. L. K. Cow Milker—Continued.

Have you or your customers noticed any difference in the machine milk and that drawn by hand, as to flavor, keeping quality or the quality of products made therefrom.	What saving is there in your opinion in using the machine in herds with less or more than 30 cows?	What are your views at present as to the practicability and economy of the B. L. K. milking machine under your conditions of dairying.
None........................	Would use a machine even in a small herd.	Very satisfactory; run machine myself.
No..........................	Great saving in work.......	It is a great help.
No; all depends on how machine is taken care of, attend to cleaning of machine myself.	Some in time,—and done easier.	Only help for the hired man. Cannot trust him to wash up. So when milking is done they go on and I have to stay and wash. If I did not have a machine, I would not put one in.
Not that I know of. May be cleaner.	Would be harder to keep men without machine.	I want the machine so I can milk cows if no one else is around. Satisfactory so far. Have had hired man and wife run it without any trouble.
No.........................	Cut out a man or two for milking. Others can start other work and get to the field earlier and can stay longer in P. M.	O. K. Put in because it was impossible to get milkers. Satisfactory solution of the hired help problem.
No. Have not had a can sent home since we had machine. Only 2 before which were accidental.	Saves in number of hands necessary for milking. Have work for enough men to do milking in summer, but not in winter. With myself and boy can attend to milking, if necessary.	Satisfactory. Does well as a solution of the milking problem. Milked part of herd by hand for a time and found that they went down and up with machine-milked cows. Buy fresh cows and keep them as long as they pay. Do not raise any calves.
Not noticed any difference ourselves and customer has not made any comment.	Don't know. Saves a little muscle and time.	Think it is practical........
No.........................	Saves labor. When the boys were threshing I milked the 35 cows in less than 1½ hours. By hand it would have taken nearly three hours.	Think it is practical........

TABLE XXII.—DETAILS OF FIRST REPORTS OF WISCONSIN DAIRY FARMERS USING THE B. L. K. COW MILKER—Continued.

Herd No.	Have you noticed any difference in the efficiency of the machine with old or with young cows, with fresh cows, or such advanced in their lactation.	How does the yield now obtained compare with what you have had at this time in earlier years under hand milking.	What disposition do you make of your milk.	Have you had any difficulty in running the machine so far.	Have you or your customers noticed any difference in the machine milk and that drawn by hand, as to flavor, keeping quality or the quality of products made therefrom.	What saving is there in your opinion in using the machine in herds with less or more than 30 cows.	What are your views at present as to the practicability and economy of the B. L. K. milking machine under your conditions of dairying.
39	Heifers milk out quicker and cleaner than an old cow. Fresh cows work better.	Way down but lay it to feed. Do not think it is the machine's fault.	Creamery......	Only the engine.	No..........................	Two of us can do the farm work if we get the milking done. Would not try to milk so many cows by hand.	Seems to be practical. Can tell better when I have had one 4 or five years.
40	Cows vary some.......	Just as much..........	Ship cream....	Very little.....	No..........................	One to three men...........	Very satisfactory. Operate the machine myself.
41	Young cows seem to be best. Fresh cows need the best care.	About the same.......	Block and brick cheese.	No.............	About the same, but cleaner.	With less than 30 cows, one good man at milking time.	The most work-saving machine on the farm. It is used every day and will do the best of work if tended right.

TABLE XXIII.—SECOND REPORTS OF WISCONSIN DAIRY FARMERS USING THE B. L. K. COW MILKER.

Herd No.	Do you still use machines? If not, why?	Has machine been used continually?	Experience.	Number of cows milked by machine.	Number of machines used.	Number of sets mouth-pieces and teat-cups used.	Number of men employed for machine milking.	Time required for: Preparation.	Milking.	Cleaning.
			Months					Minutes	Minutes	Minutes
1	Yes	Yes	25	32	3	9	1	15	75	20
4	No*	No, toward time when discontinued.	18	23—30	3	8	1	10	60	20
7	Yes	Yes	17	24	3	8	2	5	40—50	15
8	Yes, part of herd	Yes	18	20	2	8	1	10—15	60	15
10	Yes	Yes	17	40	4	13	2	2	40	15
11	Yes	Yes	17	26—30	3	7	2	10	40	5
12	No. Had too much loss of milk and spoiled the cows' udders.	Until discontinued	3	66	4	12	3	10	90	20—30†
13	Yes	Yes. Except while cementing the stable.	16	28	2	6	1	5—10	75	5—10
14	Yes	Not in summer. Cows then low in milk or dry.	16	23	3	8	1	5	50—60	5
15	No. Did not think I was getting enough milk and had more cases of garget than at any time before.	Until discontinued	3	60	4	12	2	10—15	100	30
23	No. Cows do not seem to hold up s well.	No‡	2½	25	4	12	2	....	....	....

*"Had more and better help; cows did not do as well as I thought they ought to, did not seem to hold out; flavor of cream did not seem as good as usual; extra washing; and expense of gasoline." †For three men. ‡Machine used occasionally after two mouths, the cows being milked by machine for single milkings or a day at a time only, with unfavorable results.

TABLE XXIII.—SECOND REPORTS OF WISCONSIN DAIRY FARMERS USING THE B. L. K. COW MILKER—Continued.

Herd No.	Do you manipulate udders during milking?	Are machine-milked cows stripped, and how necessary?	Weight of strippings per ten cows.	Difficulty in operating machine.	Vacuum maintained.	Average cost of power per month.	What parts of machine have needed repairs?	Total expense for repairs, to date.
			Lbs.					
1....	Only if flow stops too soon.	Into cups. To be sure they are milked clean.	As close as average milker.	No; pails too small.	15 -16	....	Only springs and mouth-pieces.	About $3 00
4....	Yes, toward close...	Yes. To make sure they are milked clean.	About 2 lbs......	No...............	15½	$1 80	Only springs and mouth-pieces.	6 00-8 00
7....	Some cows. Others do not require it.	Into cups if not dry.........	Not weighed.....	No...............	16	3 00	Chiefly springs & mouth-pieces.	2 50
8....	Yes, when about half done.	No; not with these cows...	....	No...............	15½-16	3 25	Only mouth-pieces.	About 10 00
10....	Yes..................	Yes..........................	1½	No...............	16	2 25	Mouth-pieces....	About 10 00
11....	Yes..................	Yes, much depends on way machine is operated.	2-4	Some, in getting the cows to give down their milk.	15½	1 50	Mouth-pieces & teat-cups.	*30 00
12....	Yes, thoroughly.....	Yes, because some gave as much as a gallon after using machine.	Varied..........	No...............	....	....	None............	None.
13....	Yes..................	Yes, on certain cows........	1	No...............	15	1 00-1 50	Mouth-pieces....	1 50
14 ...	Yes..................	No, not necessary..........	....	No...............	15½	1 00-1 25	....	7 00
15....	Yes, when nearly done.	Yes, very necessary.......	....	No...............	15 -16	6 75	Only replacing mouth-pieces and teat-cups.	....
23....	Yes..................	Yes, very important to do so.	....	No...............	15½-16	1 80	None............	None.

* For mouth-pieces, rubber rings, springs and for a bad break in the pump ("the result of carelessness").

DETAILS OF SECOND REPORTS OF WISCONSIN DAIRY FARMERS USING B. L. K. COW MILKER.

The following two questions, in addition to those given in the preceding table, were answered by the farmers in their second reports: A. What saving of help do you find in the use of the machine? B. What is your general view as to the practicability and economy of the machine after more than a year's experience?

HERD No. 1. A. Would need three men to milk these cows. B. Believe it a success under my conditions. Makes one more independent of hired help. Believe I get as much milk from my herd as I would by hand with such help as I would be likely to have.

HERD No. 2. "My experience is the same as I gave you one year ago, although I am not using it now. A few months after reporting to you I had to stop using them on account of a rupture that appeared on me which I claimed came from the position one has to be in in applying the machine and getting up and down so often. I afterward entrusted the machine to the hired man's care, but he did not have such good success and we stopped using it. But I think the machine could be made a success in a good man's hands. With the exception of about five cows out of 40 the machine did well, especially on young cows, as long as I was using it myself." (Sept. 1908.)

HERD No. 3. "Use of machine discontinued after first year, as fewer cows were kept and more help was available for hand-milking. Herd reduced to 13 cows in milk with which number I did not consider it worth while to use machine. I had trouble with only one cow, a very large producer, often reaching 80 pounds of milk in a day, and being very particular as to how she was milked by hand. This one did not give down well to machine. Otherwise nothing to add to first report." (Sept. 1908.)

HERD No. 4. A. None. The one who runs machine has hard work while the rest take it easy. B. Don't think much economy.

HERD No 5. We have not been running our milking machine this summer, the principal reason being our inability to get a competent man to run it. However I have not lost faith in it, and expect to start it again in another year after I get my barns arranged, and can get a careful man to run it. We will have a lot of young cows coming on, and I find that the younger cows take more kindly to it than the older ones. (July, 1908.)

HERD No. 6. Farm and machine sold since first report. Present owner has not commenced using it. (Sept., 1908.)

HERD No. 7. A. I have one man do the milking, one to weigh and separate milk and feed calves, etc. So for milking we practically save two men's time. B. I would not be without a machine if I could get one. Have weighed my milk for the past three years and I find that, as a rule, cows have done considerably better with machine. Machine is all right, but you can not trust it to every man to use as some abuse it and accordingly neglect same, as a hand milker would some time do it.

HERD No. 8. A. Saves $100 a year. One or two men part of the time. B. With some cows. Depends a good deal on the operator. Cannot run

it himself. One son is successful, the others are not. Cannot say milk is cleaner. No difference in the production of hand milked and machine milked cows.

HERD No. 9. We have discontinued the use of the milker temporarily and possibly permanently. A number of the cows did not do well at all and since taking up hand-milking have improved very much. These cows insisted in not giving down at all after the milker, and the consequence was nearly went dry, but really the most serious drawback was the time; although we had three milkers yet it took nearly double the time it did by hand. Another reason, my son purchased part of the farm and he did not feel like putting so much money into it; the chances now are I shall try and dispose of it. (Aug. 1907).

HERD No. 10. A. Saves two milkers. B. Good if advice is followed. Machine has been used continually.

HERD No. 11. A. Saves one man. B. They are alright if handled according to instructions. One must use judgment in operating the machine to get good results.

HERD No. 12. A. The saving of help would be quite an item if they gave satisfaction with the work. B. I think these machines are a curse to the dairy farmer and especially to the man who has a pure-bred herd of cows and the man who has put in time and money to build up a good herd. From the use of the machines we have 9 cows with spoiled udders, they lost from one to three quarters each. Another case is of easy milking cows that they leaked milk all the time this summer which they never did before. In several cases the cows do not give more than half the amounts of previous years and the cows have a tendency of going dry much earlier than previous years.

HERD No. 13. A. Saves 1 to 2 men in milking. B. Successful to certain extent. Not operated personally all the time.

HERD No. 14. A. Saves one man. B. Satisfied with results and will continue to use machine.

HERD No. 15. A. No. Same help needed for other farm work. B. It is neither. If it is saying anything, I believe it is better than every Tom, Dick and Harry for milking cows. Got it to make dairy work easier and to keep more cows with same help. None of us found it easier, with the bending down under the cows and the care of the machinery.

HERD No. 23. A. None saved. B. From my experience I don't think machine-milking satisfactory for a breeder of pure-bred stock, or any dairyman who is trying to improve his herd.

Some Conditions Which Influence the Germination and Fertility of Pollen

E. P. SANDSTEN.[1]

The question of barren and unproductive orchards is highly complex and involves a number of problems which have scarcely been touched by experimenters. In general, we know that because of lack of cultivation, fertilizers, spraying and pruning, orchards may be unproductive and unprofitable even though the location and soil may be favorable, but relatively little is known of the influence of these environmental factors upon the production and fertility of the pollen. The work described in the following pages is confined principally to a study of the pollen grain as affected by various external conditions, together with a brief presentation of its purely botanical relations.

MORPHOLOGY OF POLLEN.

The pollen grain which is popularly associated with the male element of the plant is botanically a microspore, homologous to the microspores of the vascular cryptogams. They are thus true spores, which, upon germination, produce the sexual or gametophytic plants.

The general morphology of pollen is so well known that only a brief resumé is here given: In the development of the pollen grain the cells below the epidermis gradually become differentiated into two distinct layers. The outer layer together with the epidermis of the anther sac gives rise to the walls of the anther sac, while the inner layer develops into the archesporia or mother cells. The arrangement of these mother cells, or archesporial cells, vary greatly in different genera of plants.

1 Formerly Horticulturist at this station, resigned June, 1909.

They may be arranged in longitudinal rows, or in nests, and if arranged in rows, they are usually in pairs and equally distributed on both sides of the vascular strands.

As development proceeds, separation of the archesporia and the wall tissues becomes more clearly defined. At this point the growth of the wall tissue stops while the archesporial tissue further divides giving rise to the pollen mother cells. The innermost layer of the wall or the layer surrounding the pollen mother cells, now deliquesces and the resulting mucilaginous fluid completely surrounds the pollen mother cells.

Figure 1. Relative size and shape of pollen of several plants. 1. Tomato; 2. Peach; 3. European plum; 4. Pear; 5. American plum; 6. *Asparagus sprengeri*. Magnified 120 times.

As the process of development proceeds, the growth of the pollen mother cells undergoes further modification, becoming in many instances, greatly thickened and stratified. The pollen mother cells in the process of further development divide into four parts, each of which in turn becomes invested with its own wall. To begin with, these walls are thin and hyaline in color, but as they ripen the walls thicken and become sculptured and variously colored. The spores resulting from the last division are the pollen, which, upon germinating, become the male or gametophytic plants containing the fertilizing element or spermatoplasm.

The pollen grains are unicellular in most species of plants though several exceptions may be noted. For example, those of conifers and cycads, but as far as known only one of these cells takes part in the fecundation.

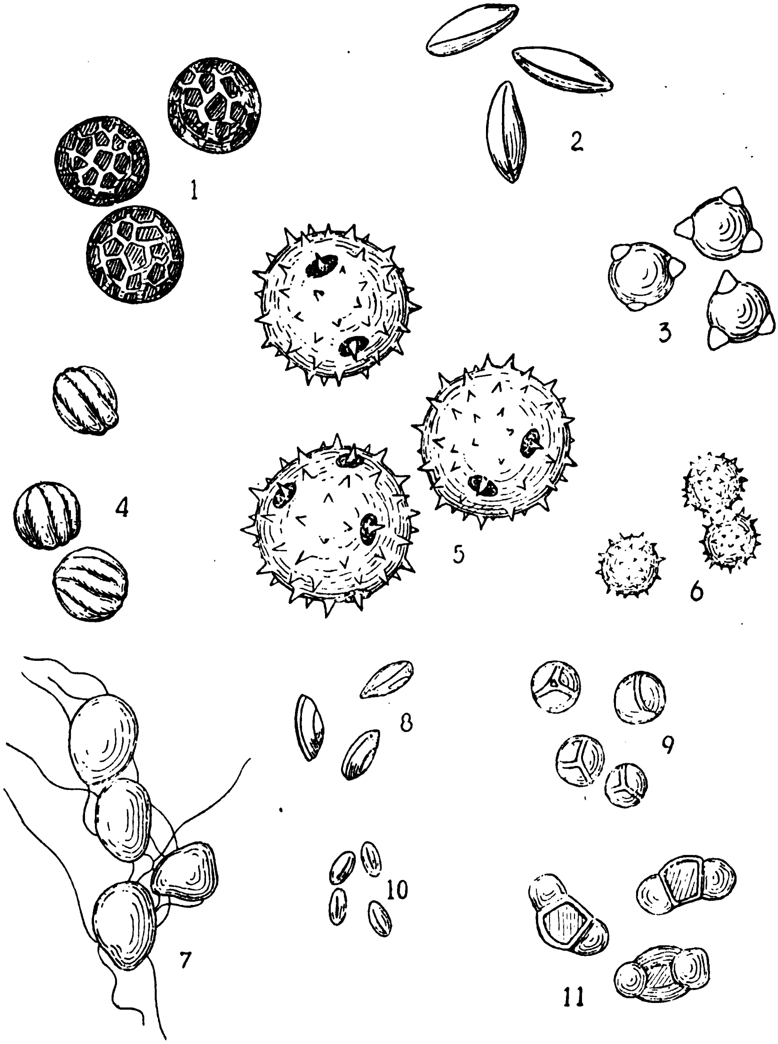


Figure 2. Relative size and shape of pollen of several plants. 1. *Cobea scandens*; 2. *Amaryllis*; 3. *Pelargonium*; 4. *Salvia splendens*; 5. *Pepo*; 6. *Calendula officinalis*; 7. *Fuchsia speciosa*; 8. *Brassica nigra*; 9. *Cannabis sativa*; 10. *Lycopersicum esculentum var*; 11. *Pinus*. Magnified 120 times.

The size of the pollen grains varies greatly in different genera, and even in species and varieties within the same genius. The size of the pollen grain is also greatly influenced by the environment, especially by such environmental factors as food, light and heat. Table I gives this variation.

TABLE I.—THE SIZE OF THE POLLEN FROM VARIOUS PLANTS.

Species.	Diameter In Millimeters.	
	Minimum.	Maximum.
Abutilon striatum	0.0617	0.0792
Ageratum conyzoides	.0161	.0176
Allium Neapolitanum	.0382	.0588
Azalea indica	.0441	.0588
Oxalis cernua	.05	.052
Begonia rubella	.0147	.0235
Cheiranthus cheri	.0164	.0308
Chrysanthemum leucanthemum	.0241	.0297
Cucurbita Pepo	.023	.023
Cuphea ignea	.0176	.0264
Cyclamen latifolium	.0176	.0179
Dianthus caryophyllus	.05	.0588
Solanum jasminoides	.0161	.0266
Lycopersicum esculentum	.025	.0264

The pollen is distributed by various agencies such as wind, water, and insects, and many plants exhibit a marked adaptation of the flower for such distribution. Plants which depend principally upon the wind for their pollination are termed anemophilous plants, and the pollen anemophilous pollen, and those pollinated by insects are called entomophilous plants, and the pollen is named accordingly.

The adaptation of the pollen to these two means of distribution is very interesting. The anemophilous pollen is mostly spherical and free with a dry outer covering to prevent large masses of pollen from adhering. The surfaces are also variously sculptured and modified to permit the wind to take hold of it. In the case of pine, the pollen is provided with bladder-like appendages to permit its being borne upon the wind.

Entomophilous plants, which depend upon insects for distribution of pollen, have developed highly colored flowers, honey-secreting glands, and in many cases, perfume-secreting glands to attract insects. In many instances, the pollen is surrounded with sticky substances so as to adhere to the feet and other parts of the insect. In some species of plants, the pollen grains are covered with oil. This covering serves two purposes; first, to

prevent rapid evaporation which is a great desideratum in many species of short-lived pollen; second, to make the pollen grains adhere to the surface.

The various coverings and secretions surrounding the pollen grains render them less impervious to water. The time of germination is greatly influenced by the material of the covering, as is also the thickness of the wall layers.

PHYSIOLOGY OF POLLEN.

The composition of pollen, according to M. Molisch and others, is fairly constant in different species of plants. Starch is generally present and out of 110 species examined by H. Molisch[1] 101 gave starch reactions. A large number of species were tested during these experiments and in every case a starchy reaction was obtained. Besides starch, other food reserve products such as sugar, fats and albuminoids were found to be present in varying amounts. The presence of ferments has been noted by Van Tieghens[2] and J. R. Green.[3] Diastase was found in the pollen of *Helianthus, Gladiolus, Anemone, Pelargonium,* and other plants.

The method employed by Green to test the presence of diastase was used by the writer, and may be described as follows: pollen grains of given species were ground in a porcelain mortar and a small quantity of a 5 per cent solution of sodium chloride was added, and also a few drops of 0.2 per cent solution of potassium cyanide. The solution was allowed to stand for a few hours. The decoction was then filtered and to six cc of the filtrate and a few drops of a 1 per cent starch paste was added. This was then set aside for three hours. after which it was tested with Fehling's solution. A quantative determination was made to be sure that all the starch had been converted. A part of the solution was afterwards tested for starch, but in each instance it gave no starchy reaction.

Several tests were made for invertase without starch paste, using a 2 per cent solution of cane sugar which was added to the pollen decoction. The cane sugar was in every case reduced

---

1 Sitzber. K. Akad. Wiss. (Vienna) Math. Naturw. Kl., Bd 102, Abth. I, p. 423.

2 Ann. Sci. Nat. Bot. 1869, Ser. 5, 12:312.

3 Phil. Trans. Roy. Soc. London, 1894, Ser. B. 185:385.

as indicated by Fehling's test. To test for sugar, a part of the decoction was used without any addition, and the usual reaction was obtained. In every test made by the writer using a large variety of pollen, diastase and invertase was found present. Van Tieghens found that the action of diastase and invertase played a definite part in the nutrition of the pollen tube, as in its growth through the style. During the growth of the pollen tube, the reaction of starch gradually becomes more feeble, showing the conversion and consumption of the reserve food by the pollen plant.

The presence of enzymes in the pollen grains cannot be doubted as they play an important part in the metabolic process of the pollen plant. Their office is to digest the various food substances. The presence of the diastase and invertase was found also in the styles and stigmas of a number of plants. This fact would indicate that the pollen tube in traversing the styles obtains nourishment from the surrounding tissue.

When one considers the great disproportion in size between the pollen grain and the pollen tube, when the latter is full grown, it seems almost impossible that there should be food enough stored up in the pollen grain to provide for the growth of the pollen tube. A conclusion that the pollen tube is capable of taking food from the surrounding tissue through which it passes on its way to the ovary, is inevitable.

Most pollen grains or pollen plants are negatively aerotropic and chemotropic. These characteristics are very pronounced when the pollen grains are germinating in artificial cultures. The germination is always hastened in bright sunlight, but the subsequent growth of the pollen tube is in most cases greatly retarded if the culture is kept in bright sunlight. The direction of the growth of the pollen tube is away from the light, that is, negatively heliotropic.

The reaction of pollen to staining fluids varies considerably. Pollen of the *Compositae* when treated with sulphuric acid and indigo blue, gives an instantaneous reaction, and when heated with iodine blue and nitric acid, the same reaction is obtained. The reason why many pollen grains fail to stain readily is due to the nature of their covering. Under prolonged treatment all pollen will take stain.

GERMINATION OF POLLEN.

Technique. The apparatus necessary for the germination of pollen is simple. The glass cells used by the writer were mounted on ordinary glass slides, and made secure by dipping the end attached to the slide in melted paraffine. The pollen was then mounted in the germinating media on cover glasses and the same inverted over the cell in the form of hanging drops. The cover glasses were made secure to the glass cells by anointing the tops of the cells with a thin film of vaseline. The transfer of the pollen to the cover glasses was accomplished by the aid of an ordinary mounting needle. Previous to the mounting of the pollen, the cells were half filled with distilled water to prevent the germinating media from drying out. The respective cells were then properly labeled. The temperature in the laboratory varied from 15 to 23 degrees C. The pollen from a number of high temperature plants were placed in a hot-water oven under constant temperature, but this treatment resulted in little difference in the time and percentage of germination.

Culture Media. Various culture media were tried in order to ascertain the one best adapted for the work. It was found that a large number of pollen germinated readily in the following sugars: saccharose, glucose, levulose, lactose and maltose. In almost every case saccharose was used. The invert sugars and lactose did not yield as good results as cane sugar. Maltose gave quite uniform results. Dextrine, gum, glycerine, and olive oil were tried, but the results were not satisfactory. Decoctions of the style and stigma were used and the pollen of the same plants germinated freely in them. These media were abandoned, due to the difficulty of getting the decoctions sufficiently clear for mounting. Filtering the decoctions remedied this fault, but it was found to be difficult due to the consistency of the solution which in many cases is quite viscid. Dilute gelatin proved a failure. Several species of pollen germinated in glycerine, but the subsequent growth of the pollen tube was retarded. Pollen of *Phaseolus multiflorus* were found to germinate best in olive oil. Pollen of tomatoes required a slightly acidulated 10 per cent solution of cane sugar.

INFLUENCE OF SUNLIGHT ON GERMINATION OF POLLEN.

The result of the experiment with effect of cloudy weather upon the germination of tomato pollen is of great interest to the grower who is forcing tomatoes. Experiments show that bright sunshine is very favorable to a good setting of fruit, while rainy and cloudy weather is unfavorable. It should also be noticed that the tomato anthers do not open readily in cloudy, wet weather. Experiments in greenhouse culture with tomatoes during the winter months show conclusively that a greater number of fruits to the cluster was set during the period of bright sunshine than during the following period of cloudiness; also that the development of the anthers was greatly retarded by the cloudy weather.

Experiments with the pollen of apples, including the Duchess, Wealthy, and plums of *Domestica* and *Americana* varieties gave quite different results as shown by Table II.

TABLE II.—PERCENTAGE OF GERMINATION AND RATE OF GROWTH OF POLLEN IN SUNSHINE AND CLOUDINESS.

Temperature.	No. of observations.		Average percentage of germination.		Rate of growth in mmm per hour.	
Degrees C.	In sunshine.	In cloudiness.	In sunshine.	In cloudiness.	In sunshine.	In cloudiness.
			Prunus Americana.			
34	3	3	70	72	48	37
31	2	2	68	67	38	33
33	3	3	69	70	45	43
			Apple.			
33	4	4	71	70	52	41
32	3	3	68	70	50	45
33	3	3	69	68	48	45
			Prunus Domestica.			
*32	2	2	62	60	42	38
*30	3	3	60	59	40	38
*33	2	2	64	65	45	43

* Medium, a 3 per cent cane sugar solution.

The large number of species of pollen germinated in distilled water showed no subsequent growth of the pollen tube. At first, the writer believed that such germination was simply the protuberance of the cell contents at the weakest point of the cell wall due to the imbibition of water, but on examination it

was found that this protuberance seems to have come from a definite part, and that the pollen tube actually extended in length to about the diameter of the pollen grain.

The germinating media were made up as follows: crystalized cane sugar and distilled water were weighed out on an analytical balance, and both placed in small vials closed with cotton to prevent contamination. In spite of all precautions, it was found that the solutions did not keep fresh for more than a few days, and for this reason new solutions were made at the beginning of each series of experiments. Poor results were obtained if the solutions had started to ferment. Table III shows the minimum, optimum and maximum degrees of concentration of germination media of cane sugar for species named.

TABLE III.—MINIMUM, OPTIMUM AND MAXIMUM DEGREES OF CONCENTRATION OF GERMINATION MEDIA FOR SPECIES MENTIONED.

	Per Cent Of Sugar Solution For Treating.		
	Minimum.	Optimum.	Maximum.
Ricinus communis	5	5	15
Robinia Pseud-acacia	10	35	50
Rumex Acetosella	15	35	40
Salvia splendens	10	20	35
Sambucus nigra	15	25	40
Sedum acre	1	20	45
Solanum jasminoides	10	20	30
Tilia Americana	20	20	25
Tradescanta Reginae	15	20	35
Trifolium hybridum	15	25	50
Viola odorata	2	20	45
Trifolium repens	15	20	40
Vitus labrusca	15	20	30

RESULTS OF GERMINATION TESTS.

The phenomena of germination and the subsequent growth of the pollen tube are highly interesting. The first noticeable change is the swelling resulting from the imbibition of the medium. The rapidity of the process depends upon several factors:

1. The nature and thickness of the perine (outer) layer.
2. The age and vitality of the pollen.
3. The nature and concentration of the germination medium.
4. The temperature.
5. The season.
6. The sunshine.

In most species of plants there seems to be a definite spot from which the germination tube issues, though the spot cannot be definitely located especially if the pollen has a spherical outline. Pollen which has a cylindrical outline will germinate from one of the long poles. Triangular pollen will germinate from one of the apices, but which one is impossible to determine beforehand. At first, the young pollen tube appears

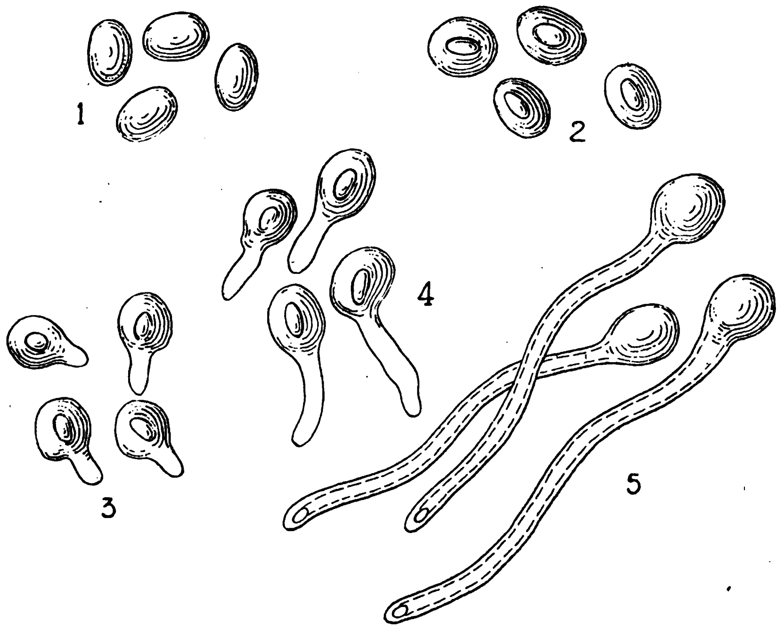


Figure 3. Stages of germination and growth of the tube of apple pollen. 1. Normal pollen; 2. Appearance of pollen in a 3 per cent solution just before germination; 3. Length of pollen tube after 20 minutes growth; 4. Length of pollen tube after 60 minutes growth; 5. Length of pollen tube after six hours growth. Magnified 120 times.

like an expansion or protuberance of intine layer through the extine and perine layers. (See Figure 2.) The young pollen tube is at first hyaline in color and almost transparent. The growth at this stage is very rapid. Soon small hyaline colored bodies issue from the pollen grains and move downward into the tube. These bodies generally move in lines parallel to the walls of the tube.

About the time the pollen tube has reached its maximum length, the hyaline bodies, which have become reduced in number, migrate to the lower end of the tube, and at this time

the fecundating nucleus is visible at the extreme end of the pollen tube, surrounded by a dense mass of protoplasm. Close observation has failed to disclose whether the germinating nucleus is formed in the pollen tube, or if it migrates from the body of the pollen grain, though the latter seems to be more probable.

The rate of growth of the pollen tube is dependent upon the temperature, proper medium, and in some cases upon the amount of sunshine. The effect of sunshine is very noticeable in the case of the tomato. Repeated experiments showed that the germination was increased from 25 to 50 per cent in sunshine. It was also found that the production and the maturity of tomato pollen were much affected by cloudy weather. Table IV gives the results of observations upon the rate of germination under the same temperature and culture medium in cloudy and sunny weather.

TABLE IV.—PERCENTAGE OF GERMINATION AND RATE OF GROWTH OF TOMATO POLLEN IN SUNSHINE AND IN CLOUDY WEATHER.

Temperature.	Number of observations.		Average percentage of germination.		Rate of growth in mmm. per hour.	
Degrees C.	In sunshine.	In cloudiness.	In sunshine.	In cloudiness.	In sunshine.	In cloudiness.
33..........	3	3	66	41	45	27
34..........	2	2	64	42	43	28
36..........	3	3	68	46	49	32

Remarks: The medium used was 9 to 10 per cent cane sugar slightly acidulated.

Repeated attempts were made to discover, if possible the manner of growth of the pollen tube, but in this the writer was unsuccessful. No cell division or differentiation was noticed. It was noted, however, that at the remote end of the pollen tube, the protoplasm was most dense, especially at the time when the tube had reached its maximum length. In all cases the fecundating nucleus was surrounded with dense protoplasm, while the rest of the tube was entirely transparent and the contents of uniform consistency. The cell walls of the pollen tube were visible.

THE EFFECT OF HIGH TEMPERATURE, IN A DRY ATMOSPHERE, ON THE VITALITY AND GERMINATION OF APPLE AND PLUM POLLEN.

In order to ascertain the effect of high temperatures on the vitality of apple and plum pollen, eight lots of apple and plum pollen were placed on watch glasses. Seven of each kind were subjected to a constant temperature for one-quarter of an hour in a drying oven. Lot number eight of each kind was kept for check. The temperatures of the lots varied from 40 to 100 degrees C. From each lot, samples were taken separately and tested for germinating power. The accompanying Table V shows the results obtained.

TABLE V.—THE EFFECT OF HIGH TEMPERATURE IN A DRY ATMOSPHERE ON THE VITALITY AND GERMINATING POWER OF POLLEN.

Lots.	Temperature.	Time subjected.	Time required for germination.	Strength of germinating medium.	Per cent of germination.	Remarks.
	Deg. C.	Minutes.	Minutes.	Per cent		
				Apple.		
1.........	40	15	8	6	50	Normal.
2.........	50	15	9	6	52	Several pollen grains bursted.
3.........	60	15	7	6	40	Large number bursted.
4.........	70	16	9	6	32	Large number bursted.
5.........	80	15	8	6	18	Large number bursted.
6.........	90	15	....	6	10	
7.........	100	15	....	6	1	
8.........	30	....	10	6	65	Normal (check.)
				Plum.		
1.........	40	15	14	3	60	Normal.
2.........	50	15	17	3	61	Normal.
3.........	60	15	20	3	54	Many pollen bursted, growth slow.
4.........	70	15	31	3	30	Swelling less than normal.
5.........	80	15	28	3	23	Swelling restricted, growth slow, many pollen bursted
6.........	90	15	32	3	8	Same as Lot 5.
7.........	100	15	....	3	....	All apparently dead.
8.........	30	15	12	3	63	Normal.

The decrease in the percentage of viable pollen was quite uniform with the increase of temperature, while a relatively high percentage of viable pollen was found in lots five, six and seven. It is quite doubtful whether all of these were fertile, since the growth of the pollen tubes after germination was considerably retarded, and a normal length in the germination

medium was in no case obtained. The experiment shows, however, that the vitality and the power of the pollen to resist the extreme heat is great.

In Lots 2, 3 and 4 inclusive, the germination and subsequent growth of the pollen tube were normal with the exception that a longer time was required for the pollen to germinate. It is quite noticeable that as the temperature increased, the length of time required for germination was correspondingly increased. For example, Lot 1 subjected to a temperature of 40 degrees C. germinated in 10 minutes, or about the same as the check under normal conditions, while Lot 4 subjected to 70 degrees, required 30 minutes to germinate. The pollen in Lot 7 had been subjected to high temperatures and was considerably shrunken and required a longer time to absorb sufficient moisture to effect germination.

EFFECT OF HIGH TEMPERATURE, IN SATURATED ATMOSPHERE, ON THE VITALITY OF APPLE POLLEN.

Eight separate lots of apple pollen were placed on watch glasses. Seven were subjected to constant temperatures ranging from 40 to 60 degrees C. in a saturated atmosphere in a drying oven. One lot was kept under normal condition as a check. The results as shown by Table VI were quite different from the former experiment in which the pollen were subjected to dry heat. The pressure of moisture undoubtedly caused the pollen to imbibe water and the rupture of the cell wall.

TABLE VI.--THE EFFECT OF HIGH TEMPERATURE, IN AN ATMOSPHERE SATURATED WITH MOISTURE, ON THE VITALITY OF APPLE-POLLEN.

.	Temperature.	Time subjected.	Time required for germination	Strength of germinating medium.	Germination.	Remarks.
	Deg. C.	min.	min.	Per cent.	Per cent.	
1	40	15	8	6	50	Normal.
	50	15	9	6	30	Several pollen grains bursted.
3	60	15	7	6	18	Large number bursted.
4	70	16	9	6	6	Bursted.
5	80	15	8	6	2	Bursted.
6	90	15	....	6	0	
7	100	15	....	6	0	
8	30	15	10	6	65	Normal (check).

INFLUENCE OF LOW TEMPERATURE ON THE VITALITY OF POLLEN.

A general impression seems to prevail among fruit growers that a light frost kills pollen and as a consequence the fruit fails to set. A careful study of the nature of the pollen reveals the fact that the mature grains are quite well protected. Nature has provided them with comparatively heavy coverings to resist ordinary winter conditions. The uncertainty of fulfilling their mission is, undoubtedly, responsible for this precaution, for their existence is indeed precarious. Probably not one pollen in a thousand is given a chance to germinate and fertilize the ovary. To guard further against the destruction of the pollen, the anthers open at different times and at intervals of from one to four days, though there seems to be a close relationship between the time of dispersion of pollen and the receptivity of the stigma. This successive opening of anthers for the dispersion of pollen provides for an abundance of pollen at the right time.

To study the effect of freezing temperature on the pollen, the following experiment was made with apples, pears, plums and cherry pollen. Ripe pollen was collected on watch glasses, two lots of each kind. One lot was set aside as a check for use in comparing the results. The other set was placed in a freezing cabinet registering a temperature of between —1.5 and —1 degrees C. The watch glasses were kept in a freezing cabinet for six hours, when they were taken out and tested in the ordinary way for germinating powers. The checks were kept in the laboratory in a temperature ranging from 21 to 24 degrees C. Table VII gives the results.

TABLE VII.—EFFECT OF LOW TEMPERATURE ON THE VITALITY OF POLLEN.

Variety of Pollen.	Temperature of freezing cabinet.	Time exposed.	Germination after exposure.	Germination of normal checks.	Time of exposure required to germinate.	Time of exposure required to germinate checks.
	Deg. C.	hours.	per cent.	per cent.	minutes.	minutes.
Apple	—1.5	6	52	5[illegible]	47	20
Pear	—1.5	6	43	50	41	28
Plum	—1.5	6	56	62	30	15
Cherry	—1.5	6	45	68	33	12
Peach	—1.5	6	30	57	25	10

The results as indicated in Table VII showed conclusively that a temperature of —1.5 degrees was not fatal to most of the pollen used in the experiment. There was a slight falling off in the percentage of the exposed pollen as shown by comparing them with the check, but this should be expected. Many feeble pollen which would have germinated under ordinary conditions were killed by the exposure, but the percentage of viable pollen was still large enough to effect fertilization. This is especially true in the case of the apple, pear and plum pollen where the percentage of germination in the treated pollen to the untreated ones was 90 and 88 per cent respectively, while the cherry and peach pollen percentage was from 60.3 to 52.6 per cent respectively.

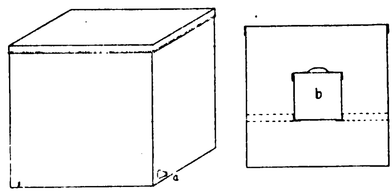


Figure 4. Freezing cabinet for in-door low temperature experiments with pollen. This consists of a galvanized iron box 18 inches square with a tight lid, with an opening at *a* for drainage. In the center of which is placed a smaller box *b*, six inches square, supported on narrow metal bars. The space around the small box containing the pollen is packed with the freezing mixture.

An examination of the cherry and plum pollen showed that they have a thinner covering and naturally would not be able to withstand as low temperature as apple and pear pollen.

The difference in time required by the treated and untreated pollen to germinate was quite great, but the rate of growth after germination of the treated and untreated pollen was about the same. There was no noticeable difference in the development of the pollen tubes between the treated and untreated ones. Just why it should require the pollen exposed to low temperature longer to germinate is difficult to say, but it is probably due to the change in the cell walls or in the constituents of the protoplastic contents within.

EFFECT OF LOW TEMPERATURE ON THE RECEPTIBILITY AND VITALITY OF THE STIGMAS.

A study of the effect of low temperature on the pollen, suggested the probability that the stigma may be more susceptible to low temperature than pollen. It was found that a temperature of —1 degree C. caused permanent injury to the stigma of apple, pear, peach, plum and cherry. A close examination of the stigmatic tissue after the treatment shows that it is

extremely tender and delicate. The surface of the stigma is composed of soft, cushion-like covering with a thin and delicate epidermal layer that offers little resistance to unfavorable conditions.

The experiment on the effect of low temperature on the pistil was as follows: Twigs were taken from trees when in full bloom, and placed in a freezing cabinet. The temperature in the freezing cabinet was kept at —1.5 to —1 degrees C. The twigs were left in the cabinet six hours. They were then taken out, and the condition of the stigmas studied under a miscroscope. The results of this experiment presented in Table VIII show that the pistil is much more suspectible to cold than the pollen, and it naturally follows that a heavy frost will kill the pistil while it may not injure the ripe pollen to any degree.

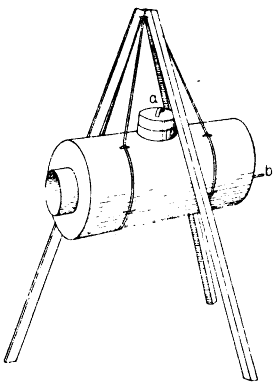


Figure 5. Freezing apparatus for out-door low temperature experiments with pollen. This device consists of a two walled cylinder with hollow core made of galvanized iron. The space between the walls is filled with crushed ice and salt through the opening *a*, at the top. A thermometer is inserted at one end of the cylinder at *b*. At the other end the inner cylinder projects three inches forming an opening through which the twig is inserted. This opening is closed with packing after the twig is inserted. The outside cylinder is two feet long and 16 inches in diameter mounted on an adjustable tripod so that the branch bearing the pollen may remain in a natural position. This device was invented by the late E. S. Goff, horticulturist of this Station.

Many horticultural writers have given as a reason for failure of fruit to set, that the juice of the stigma becomes diluted and washed off during the heavy and prolonged rains. This is often a mistaken impression, for observations seem to show that the stigma is not seriously injured by rain, though prolonged rain prevents the proper dispersion of pollen through the period of receptivity of the stigma which lasts only for a few days.

In order to determine the length of time the stigma is receptive, flowers, from which the stamens were removed before opening of the blossoms, were covered and kept under observation. From these observations, it was noted that at the end of five days all the stigmatic surfaces had become darkened and showed signs of decay, and when the pollen were placed on the surfaces, they failed to germinate.

TABLE VIII.—EFFECT OF LOW TEMPERATURES ON THE PISTIL AND THE RECEPTIVITY OF THE STIGMA.

Variety of Pollen.	Temperature.	Number of pistils.	Length of time exposed.	Condition of pistils after exposure.	Remarks.
	Deg. C.		hours.		
Apple	—1.5	15	6	14 dead	One part of the compound pistil was alive.
Pear	—1.5	10	6	All dead	
Plum	—1.5	·22	6	19 dead	Two appeared alive.
Cherry	—1.5	18	6	All dead	
Peach	—1.5	12	6	All dead	

INFLUENCE OF CULTURE AND FERTILIZER UPON THE FERTILITY OF POLLEN.

To determine the possible influence of culture and fertilization upon the production and fertility of pollen, apple pollen was gathered from a neglected orchard, which, according to the owner, had been neither sprayed, cultivated nor fertilized since the trees were set 19 years ago. The trees showed abundant evidence of neglect. Pollen were taken from six different trees and germinated in the usual way. Six more lots of pollen were taken from another orchard near the old, neglected one. This orchard was in a high state of culture, but the soil was originally the same as in the neglected orchard. The trees, however, were 14 years old instead of 19. Table IX shows the result of the germination.

TABLE IX.—GERMINATION OF POLLEN FROM NEGLECTED AND HIGHLY CULTIVATED ORCHARDS.

Lots.	Pollen from neglected orchard.		Pollen from orchard in high state of culture.	
	Germinated pollen.	Time required to germinate.	Germinated Pollen.	Time required to germinate.
	Per cent.	hours.	Per cent.	hours.
1	55	28	60	20
2	33	32	56	19
3	41	26	58	24
4	44	30	63	18
5	38	28	49	20
6	28	28	53	18

The differences in the percentage of germination from pollen in the neglected orchard as compared with those of the orchard in high culture is not strikingly great, though great enough to demonstrate the fact that all the parts of the trees or plants suffer from lack of culture and plant food. There was enough pollen in the neglected orchard to pollinate all the flowers therein, provided weather conditions were favorable. Yet it should be borne in mind that all pollen capable of germination is not capable of effecting fertilization.

No attempt was made to measure the length to which the pollen tubes were capable of attaining in culture medium. The size of the pollen from the neglected orchard was plainly inferior. They lacked in plumpness, regularity, and size as compared with the pollen from the well-cared-for orchard. The length of time required for the germination of the pollen from the neglected orchard would indicate a lower state of vitality of the pollen compared with the pollen from the cultivated orchard.

Close observation revealed the fact that the flowers in the neglected orchard were much smaller and the stamens and pistils dwarfed and deformed in many cases.

LONGEVITY OF POLLEN.

The question of the longevity of pollen is a very important one to plant breeders, and to horticulturists in general. When this work was started, the question naturally arose, whether pollen kept for any length of time maintained its vitality. In order to study this problem, we obtained apple and plum pollen from four different states. This pollen was shipped between glass slides, the edges of which were sealed together with gummed paper. The pollen arrived in perfect condition. In two cases, the pollen was on the road for four or five days. Upon its arrival it was tested at once for germinating powers. The results of these tests showed that the percentage of viable pollen was practically normal. The samples were then put aside in the laboratory in a temperature ranging from 10 to 18 degrees C.

Once a month a few pollen were taken from each lot and mounted in culture cells to test their viability. These monthly tests were continued for six months with the exception of the

last test which was made eight months after they arrived. In Table X, the Lots 1, 2, 3 and 4, came from Washington, Tennessee, Missouri, and Minnesota, respectively.

TABLE X.—LONGEVITY OF APPLE AND PLUM POLLEN.

LOTS.		First germination.	Second germination.	Third germination.	Fourth germination.	Fifth germination.	Sixth germination.	Seventh germination.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1....................	apple	47	43	44	38	39	38	12
	plum	53	52	42	35	30	18	0
2....................	apple	58	57	50	43	38	33	10
	plum	54	48	38	26	21	11	0
3....................	apple	42	46	40	38	29	19	5
	plum	60	48	42	25	18	2	0
4....................	apple	56	51	52	40	23	·23	8
	plum	50	47	38	20	12	0	0

It will be seen from this table that a small percentage of apple pollen retained its vitality for six months, while but few plum pollen retained its germinating powers this long. It should be noted in this case that the place where the pollen was kept was not perfectly dry. Often the moisture content of the atmosphere was excessive and this probably accounted for the failure of the plum pollen to germinate after six months. It also influenced the longevity of the apple pollen. Tests revealed the fact that pollen of various species kept its vitality for a rather short period in the saturated atmosphere. The pollen absorbed water quite readily and either germinated or burst open. So it may be argued that excessive moisture is detrimental to the keeping qualities of the pollen just as it is to the keeping qualities of seed. The importance of this test has a bearing upon the problems in plant breeding, as it enables the breeder to import his pollen from almost any section of the country without serious injury to their viability. It will at once make possible a wider range for crossing and the origination of new varieties.

TIME REQUIRED FOR THE POLLEN TUBE TO REACH THE OVARY.

Over 50 separate measurements were taken to ascertain the average length of style and stigma of apple, pear, cherry and plum blossoms. These measurements were compared with the

rate of growth of the pollen tube under the microscope in the artificial germinating medium. It will be seen in Table XI that there is considerable variation in the length of the pistil and it should be stated that a number of pistils that reach the maximum length in the culture medium was only five, while over 50 were close to the average length as given in the table.

The temperature condition under which the test for germination and the subsequent growth in length of the pollen tube, in this experiment were nearly that of the outside temperature; 20 degrees C. in bright sunshine.

TABLE XI.—RATE OF GROWTH OF THE POLLEN-TUBE AND TIME REQUIRED TO REACH THE OVARY UNDER UNFAVORABLE CONDITIONS.

Fruits.	Average length of pistil.	Average rate of growth of pollen tube first hour.	Average rate of growth pollen-tube second hour.	Average growth in one hour.	Time required for the pollen tube to reach the ovary.	
	mm.	mm.	mm.	mm.	Hr.	Min.
Apple	11.4	0.28	0.42	0.35	32	4
Pear	8.6	.17	.235	.235	36	36
Plum	10.1	.45	.71	.58	17	25
Cherry	10.5	.36	.54	.45	23	20

The conditions under which the pollen then were germinated and grown were less favorable. The temperature was 13.3 degrees C. and the atmosphere cloudy. The difference in the result is quite marked and shows conclusively the influence of unfavorable weather conditions.

It is a common opinion among observant fruit growers that a week of favorable weather during the blossoming time is sufficient to insure a good setting of fruit, and it may be deduced from this experiment that the opinion is correct. The actual time required for the pollen tube to reach the ovary is considerably less than a week. In order to further determine this time, the following experiment was carried on in the spring:

All the stamens were removed from 18 blossoms, pear, apple and plum, six of each kind, before they opened. The blossoms were then carefully covered with thin paper bags. After two days the stigmas were in a receptive condition and four pistils of each variety were pollinated and again covered. The remaining two of each variety were left for check. At the

end of 48 hours the bags were taken off from two of each variety of the pollinated pistils and these cut off at the base and again covered. At the end of 60 hours the remaining two pollinated pistils of each variety were uncovered and the pistils were cut off at the base and again covered. The checks remained covered during the whole period. At the end of seven days all the bags were removed and the results noted and tabulated as shown in Table XII.

TABLE XII.—TIME REQUIRED FOR THE POLLEN TUBE TO REACH THE OVARY.

Variety.	Pistils cut off 48 hours after pollination		Pistils cut off 60 hours after pollination.		Check not pollinated.	
	Number of blossoms.	Number fertilized.	Number of blossoms.	Number fertilized.	Number of blossoms.	Number fertilized.
Apple	2	0	2	2	2	0
Pear	2	0	2	1	2	0
Plum	2	1	2	2	2	0

MAXIMUM GROWTH IN LENGTH OF POLLEN TUBES.

In outlining this work it occurred to the writer that there might possibly be a certain limit to the growth in the length of the pollen tube of given species and varieties, and that the inability of the pollen tube from the pollen of short styled species to cross fertilize the ovary of a species having a long style, was due to the limited growth of the pollen tube. From 50 separate measurements it was found that the average length of the pistil of apples, pears, plums, and cherries was 11.4, 8.6, 10.1, and 10.5 mm. respectively. From the number of germination tests of the pollen of these fruits, measurements were taken and the average maximum growth in length was calculated.

TIME REQUIRED FOR THE POLLEN OF A GIVEN VARIETY TO REACH THE OVARY OF THAT VARIETY.

The time required for the pollen tube to reach the ovary was found from the germination test to be from 19 to 32 hours under favorable and unfavorable conditions; while the field experiment showed that in one case it took 48 hours for the pollen of the apple to reach the ovary. The figures are

close enough to show that the danger period from frost is comparatively short. This also accounts for the fact that often a frost during full bloom apparently does very little damage, while at other times a like frost would completely kill the essential parts of the flower.

A difference of 24 hours in time of the occurrence of a frost may make a difference between a full crop and a failure. The falling off of the petals is generally taken as an indication that the fruit is set, or that the period of receptivity of the stigma is past. This is true, but it should be stated that the pollen tube may have reached the ovary two or even three days before the petals fall, or before the pistils begin to shrivel as shown in Table XII.

CONCLUSIONS.

1. The germination and subsequent growth of the pollen tube are very similar to the germination of ordinary spores and the growth of the hyphal thread. The changes taking place in the pollen grain previous to the germination are undoubtedly similar to those that take place in the germination of the seed, and the necessary conditions for germination of the pollen grain are the same, i. e. heat, moisture, oxygen and a suitable medium.

2. The first noticeable change is the swelling of the grain due to the imbibition of water, and the rate of imbibition depends on the temperature, concentration of the culture media, and in some cases, upon sunshine. The greater the concentration, the less rapid is the imbibition and germination. In these experiments the presence of diastase and invertase, has been confirmed both in the pollen grains and in the tissues of the style and stigma.

3. Most pollen grains will germinate in a solution of cane sugar. The degree of concentration differs with the different species of plants. The exceptions noted were those of the tomato and *Phaseolus multiflorus* pollen. The former germinated best in a slightly acidulated 10 per cent solution of cane sugar and the latter in pure olive oil. The range of concentration for any given species of pollen is large, indicating differences of degree of the concentration of the juices of the stigma. For example, pollen from *Narcissus tazetta* will germinate in 1 per cent solution of cane sugar and also in a 60 per cent solution, while the

pollen from *Tilia Americana* has a range of only 5 per cent, i. e., the pollen grains will germinate in a solution of 20 to 25 per cent solution of cane sugar. It is possible that the degree of concentration of the medium in which the pollen of different species are capable of germinating and growing, may, to some extent, be a barrier against a promiscuous cross fertilization in nature and horticultural practice. However, in most cases, the range is sufficiently great to overcome these obstacles, if there were not other difficulties in the way.

4. No definite statement can be made as to the exact manner of growth of the pollen tube. The movement of reserve food from the pollen grain down to the tube was clearly noticeable, but it cannot be stated whether the fecundating nucleus, which appears at the end of the pollen tube when it had reached its maximum growth, migrated from the pollen grain or was in the pollen tube. The limitation to the growth in length of a given species of pollen may be, and undoubtedly is, a barrier against cross pollenization of relative species and varieties.

5. The vitality of pollen is not seriously effected by temperatures ranging from 25 to 55 degrees C. in dry atmosphere. Temperatures under 25 degrees seriously interfere with the germination. A temperature from 70 to 80 degrees C. in a saturated atmosphere is fatal to the pollen of the peach, apple, and plum. At a temperature of 40 to 50 degrees C., in a saturated atmosphere, the pollen burst open due to the rapid imbibition of water, and the number of bursted pollen increased as the temperature increased. This bursting of pollen actually takes place in masses of apple and plum pollen during warm spring rains. Freezing temperatures ranging from —1.5 to —1 degrees C. were not seriously injurious to the pollen of apple, pear and plum, while less than 50 per cent of peach and apricot pollen were killed by this temperature. The pistils of the varieties named were more susceptible to the low temperature than pollen. Temperatures ranging from —1.5 to 0 degrees C. killed the pistils.

6. Sunshine had little or no effect on the germination of pollen or upon the growth of the pollen tube in most plants. There was, however, a slight increase in the rate of growth in favor of sunshine. The germination and growth of the pollen of the tomato is decidedly retarded by cloudy weather, and also the anthers of the tomato require a certain amount of sunshine

for the proper development of the pollen. The same is true in several species of *Lilium*.

7. The lack of culture and fertility in orchards greatly injures the production and fertility of pollen.

8. The longevity of apple, pear, and plum pollen depends on the conditions in which it is kept. If kept in a dry place in a temperature ranging from 7 to 26 degrees C., apple pollen can be kept for six months or longer, while few plum pollen germinated after being kept for six months. Pollen may safely be shipped from one part of the country to another without losing viability or fertility.

9. Under favorable conditions it requires nine to 32 hours for the pollen tube of apples, plums, and cherries to reach the ovary when placed on the stigma or in the germinating medium. Cherry pollen requires a little over 12 hours. Under natural conditions the time required would be somewhat greater since the rate of growth is increased with the increased temperature up to the optimum degree which, in the case of apple, pear and plum pollen is 24 degrees C. This would indicate that the length of time required for the germination is considerably less than is commonly believed. Two or three bright warm days at the time of full bloom is sufficient for the setting of the fruit. The stigma of apple pollen are receptive from four to six days whether pollinated or not. Continuous rainy weather for six days would probably result in total failure of the crop.

10. The factors which effect the fertility and production of pollen over which the orchardist has control may be briefly stated as follows: suitable site, location and soil; proper planting, cultivation, sufficient amount of plant food; pruning and spraying; selection of suitable varieties propagated from bearing trees, and the planting of several varieties which flower at about the same time, to insure proper fertilization.

11. The factors over which the orchardist has little or no control are: freezing temperature, which may kill the pistil or the pollen especially before the latter are ripe or both; continuous rain during full bloom of the orchard; high temperature with a large amount of moisture and absence of wind, which causes much pollen to burst at the time of germination; and absence of insects and wind at the time of full bloom.

The Rôle of the Ash Constituents of Wheat Bran in the Metabolism of Herbivora.

E. B. HART, E. V. McCOLLUM AND G. C. HUMPHREY.

In a previous publication[1] it has been shown that wheat bran contains phytic acid in combination with potassium, magnesium and calcium. In a later publication[2] it was demonstrated that this complex was in all probability responsible for the well known laxative effect of wheat bran—a phenomenon previously held to be due to the mechanical irritation occasioned by the coarse and fibrous construction of this material. In the course of the above investigation with milch cows data were procured indicating, in certain cases, a specific physiological function for this complex. Beside this laxative effect, which manifested itself in all experiments, its withdrawal from the ration occasioned more or less disturbance of fat production, a regular reduction in the volume of urine produced daily and an increased flow of milk. In addition to the above enumerated facts, withdrawal of phytin from a ration disturbed the oestrum periods of certain individuals, while in other individuals this disturbance was but occasional.

During this early investigation a limited amount of data was collected on the metabolism of the bases associated with phytin and their channels of excretion. It is indeed entirely conceivable that the path of elimination of the ingested bases associated with phytin is responsible for such phenomena as the laxative effect and the increased urine flow. The reversal of these two

---

1 Jour. Amer. Chem. Soc., 1904, 31:564.
2 Amer. Jour. of Physiol., 1906, 16:268.

phenomena invariably took place on the withdrawal of phytin from the ration of milch cows. The other effects, such as disturbances of fat production, flow of milk, and cessation of the oestrum periods,—functions imbedded deeply in the maternal nature of the animal,—were not always highly pronounced, and when such disturbances did take place, are to be considered individualistic and at present unexplained. If it were possible to induce these last three disturbances with all individuals, then the specific relation of phytin to these physiological processes might be seriously considered, but such does not appear to be the case.

PURPOSE AND SCOPE OF THE INVESTIGATION.

It was to study further the action of the components of the phytin complex when administered separately as salts, their channels of excretion and general relation to the phenomena of constipation and diuresis, with the consequent effect on milk secretion that this investigation was undertaken.

The scope of the following experiment involved a study of:—

1. The metabolism and channels of excretion of the base and acid constituents of phytin, as well as equivalent quantities of these bases in the form of chlorides and sulphates.
2. The effect of the supply and the channel of excretion of these elements on diuresis, the character of the feces and milk flow and the complete composition of the milk.
3. The effect of withdrawal of phytin and the reduction of the crude fiber content of the ration on the character of the excreta.
4. Physiological action of prepared potassium phytate.

GENERAL PLAN.

1. Feeding to the same animal during short and long periods of time, rations differing greatly in the amount of phosphorus, magnesium, or potassium, as phytin; or rations low in natural phytin, but supplemented with magnesium and potassium, as a chloride or sulphate, or potassium as a phytate.
2. A reduction of the amount of the crude fiber in the ration of low phytin content secured by lowering the proportion of washed bran and increasing the starch content of the ration.
3. Abrupt or gradual changes from rations of high phos-

phorus, magnesium and potassium content, to rations low in all or only one of these ingredients.

4. The nutritive plane of the rations to be maintained the same except in the variation of the ash constituents.

5. The ration fed to be carefully weighed and sampled and the excreta quantitatively collected and preserved for analysis.

EXPERIMENTAL METHODS.

The cow selected was a vigorous grade Holstein, in fair flesh and with a ravenous appetite. Her keen appetite secured a complete consumption of the ration during the entire experiment. The animal was kept in an especially arranged and warmed room. She was fed from a tight box which would allow recovery of all uneaten food. The daily ration was given in two equal proportions, morning and night, and water offered at definite times. She was weighed daily; all excreta were quantitatively collected. The weights represented what was voided during the 24 hours beginning at 6 a. m. The animal was milked at a definite time, twice daily, morning and night.

The rations employed were made up, as in previous experiments, of oat straw, wheat bran, rice and wheat gluten. This ration affords a high phytin intake, consequently a high phosphorus, magnesium and potassium consumption. A basal ration, low in phytin or one low in phosphorus, magnesium, calcium and potassium was secured by extracting whole wheat bran with water after a period of soaking. The calcium content of the basal ration is somewhat increased over that of the standard ration owing to the percentage increase of this element in the washed bran. Nevertheless the daily consumption of this element is below the daily output. With the basal ration as a starting point additions of materials whose influences were to be studied, could be secured.

Sufficient feeding materials were prepared or set aside for a presumed length of the experiment and carefully sampled for analyses. The milk, urine and feces were weighed and sampled after being carefully mixed. Reserve samples of milk and urine, preserved with formalin and toluol, were set aside. Five pound samples of fresh feces were dried at 60 degrees C. for reservation. Nitrogen determinations were made on the fresh

feces. Standard methods of analyses were used in most cases.[3] Fat was determined by the Babcock method and casein by the centrifugal process checked at intervals by the chemical method. It is only necessary to state that this method gave close agreement with the chemical determinations.

SEQUENCE OF RATIONS.

An initial period of two weeks was occupied in adjusting the animal to the ration used. Actual records began November 26.

Ration 1. Fed from November 26 to December 5.

Transition Period. This was begun December 5 and was completed December 9. Previous experience had shown that a sudden withdrawal of phytin from the ration resulted in constipation. To avoid this effect the withdrawal was made gradual by the daily substitution of two pounds of washed bran for two pounds of whole bran. The wheat gluten was slightly increased from day to day until December 9 the animal was receiving two pounds. Her appetite remained keen.

Ration 2. December 9 to December 23.

Ration 1. December 23 to December 30. On the evening of December 23 the animal was suddenly changed to the ration of whole bran.

Ration 2. December 30 to January 11. On December 30 a sudden change was made from the whole bran to the washed bran ration to which was added 135 grams of potassium sulphate and 200 grams of magnesium chloride. These quantities of salts supplied approximately the amounts of magnesium and potassium withdrawn by substituting washed bran for whole bran.

Ration 1. January 11 to January 21. This change was made suddenly.

Ration 2. January 21 to February 1. A sudden change was made on January 21 from the whole bran ration to the ration in which the crude fiber intake was equivalent to that of Ration 1. This ration of crude fiber was secured by reducing the intake of washed bran from 10 to 5.3 pounds. In addition 4.7 pounds of wheat starch were substituted for the withdrawn washed bran and the amount of gluten was raised to 2.7 pounds. This period was for the purpose of thoroughly testing the laxative effect of phytin. It was thought not impossible that the in-

[3] The appreciation of the authors is due Mr. Harry Steenbock, Assistant in Agricultural Chemistry of this Station for valuable assistance in collecting a part of the analytical data.

creased intake of crude fiber with the washed bran ration might be responsible for the constipated condition. Constipation nevertheless resulted after a lapse of 10 days.

Ration 1. February 1 to February 6.

Ration 2. February 6 to February 14. A sudden change was made from the whole bran ration to the washed bran ration, plus 135 grams of potassium sulphate, equivalent in potassium to the quantity supplied by the whole bran ration. The appetite was keen and the entire ration was consumed.

Ration 1. February 14 to February 19.

Ration 2. February 19 to February 29. A sudden change was made from whole bran to the washed bran to which was added 115 grams of potassium chloride, or the potassium equivalent to the quantity supplied by the whole bran ration.

Ration 1. February 29 to March 10.

Ration 2. March 10 to March 16. A sudden change was made from the whole bran ration to the washed bran ration, plus 150 grams of crude potassium phytate. This material was prepared by extracting bran with 0.2 per cent of hydrochloric acid, allowing the strained extract to settle in barrels. The extract was made alkaline with sodium hydroxide and precipitated with barium chloride. The precipitate was thoroughly washed, carefully decomposed with sulphuric acid, filtered from the barium sulphate and neutralized to phenolphthalein with potassium hydroxide. The solution was evaporated to dryness on the water bath and the residue ground and used directly. The material had a pleasant taste and odor.

DISCUSSION OF THE DATA.

The accompanying tables were made up of either daily records or were averages of periods in which it was believed the animal was adjusted to the ration. In Tables I and II are given the amounts of various feeds used daily, together with their composition.

TABLE I.—THE RATIONS FED IN THE EXPERIMENT.

Ingredient.	Ration No. 1.	Ingredient.	Ration No. 2.
	Pounds.		Pounds.
Oat straw	10	Oat straw	10
Bran	10	Washed bran	10
Rice meal	7	Rice meal	7
Wheat gluten	1½	Wheat gluten	2

TABLE II.—COMPOSITION OF THE FEEDING STUFFS USED.

Feeds.	Water.	Protein.	Fat.	P_2O_5.	CaO.	MgO.	K_2O.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent	Per cent.	Per cent.
Oat straw	8.52	6.81	1.75	0.45	0.318	0.270	1.560
Bran	9.11	15 12	4.50	3.50	.178	1.128	1.700
Washed bran	7.55	10.80	4.25	.31	.228	.181	.098
Rice meal	12.43	8.84	.40	.25	.019	.052	.130
Wheat gluten	6.37	75.00	1.60	.47	.108	.044	.098

The comparative nutritive value of the two rations is shown by the numerical data in Table III. There is nothing to indicate that the animal did not receive an abundance of digestible organic nutrients on either ration. The dry matter digested daily from Ration 1 was 17 pounds, and from Ration 2 16.7 and 16.8 pounds. While the amounts of digested protein were 2.6, 2.6 and 2.7 pounds respectively. From this it is apparent that whatever physiological differences manifested themselves they must be attributed to other variants in the ration.

TABLE III.—QUANTITIES AND PERCENTAGES OF DIGESTIBLE NITROGEN AND DRY MATTER FED DAILY.

DATE.	ASH MATERIALS.				DRY MATTER.			NITROGEN.		
	P_2O_5	CaO	MgO	K_2O	Fed.	In Feces.	Digested.	Fed.	In Feces.	Digested.
	grams	grams	grams	grams	grams	grams	Pr ct.	grams	grams	Pr ct.
December 1- 4.	190.5	23.5	65.4	152.6	11,698	3,963	66.1	286	92.6	64.1
December 19-22.	46.7	26.0	22.5	80.4	11,982	4,370	63.5	283	87.8	68.9
February 10-13.	46.7	26.0	22.5	153.3	11,952	4,343	63.7	283	83.4	70.5

INFLUENCE OF THE SUPPLY OF ASH MATERIALS, EITHER AS PHYTIN OR OTHER SALTS, ON THE ORGANIC COMPONENTS OF THE MILK.

In Table IV are recorded the results of the gradual transition period (December 3 to 29) from whole bran to washed bran, as well as data illustrating the effect where the change in the ration was made in a single day, January 19 to 20. The table includes, in addition, records of the influence of a sudden change from a whole bran ration of large phytin intake, to the washed bran ration, plus salts added as magnesium sulphate and potassium chloride. (December 29 to January 6); an equivalent to the magnesium and potassium removed in the washed bran as potassium chloride alone (February 5 to 14). The effect of the

continuation of the respective ration initiated on December 30 and February 6 is shown in the records for January 6 and February 14. This data clearly indicates, we think, that with this animal there was no significant fluctuation in the composition of the milk as the result of a wide divergence in the quantities and forms of the injested ash constituents. It must be remembered, of course, that at no time was the animal starving for magnesium or potassium, as indicated by the fairly close balance between the income and outgo of these elements during all the periods. (See Table VIII.)

TABLE IV.—EFFECT OF SUPPLY OF BRAN AND ASH CONSTITUENTS ON COMPOSITION OF THE MILK.

Date.	Total Ash Material Fed.				In Milk.				
	P_2O_5	CaO	MgO	K_2O	Solids.	Protein.	Casein.	Fat.	Sugar.
	grams.	grams.	grams.	grams.	Per ct.	Per ct.	Per ct	Per ct.	Per ct.
December 3...	190.5	23.5	65.4	152.6	10.6	2.81	1.90	2.85	4.94
" 4...	190.5	23.5	65.4	152.6	10.8	2.80	1.95	3.20	4.80
" 5...	161.4	23.9	55.7	138.0	10.8	2.67	2.00	3.15	4.98
" 7...	103.5	24.7	39.3	108.9	10.9	2.70	2.00	3.18	5.02
" 9...	46.7	26.0	22.5	80.4	10.7	2.80	2.00	3.00	4.90
" 15...	46.7	26.0	22.5	80.4	10.3	2.68	1.95	2.85	4.77
" 21...	46.7	26.0	22.5	80.4	10.7	2.70	2.10	2.85	5.15
" 22...	46.7	26.0	22.5	80.4	10.7	2.70	1.90	2.85	5.15
" 29...	190.5	23.5	65.4	152.6	10.9	2.78	1.95	2.85	5.27
" 30...	46.7	26.0	61.9	153.3	11.0	2.75	2.00	3.00	5.25
January 6...	46.7	26.0	61.9	153.3	10.9	2.78	2.05	3.10	5.02
February 5...	190.5	23.5	65.4	152.6	11.2	2.81	1.90	2.90	5.49
" 6...	46.7	26.0	22.5	153.3	11.2	2.78	1.95	2.85	5.57
" 14...	46.7	26.0	22.5	153.3	10.9	2.81	1.95	3.00	5.09
January 19...	190.5	23.5	65.4	152.6	11.2	2.87	1.95	3.10	5.23
" 20...	41.5	21.5	18.7	78.1	11.1	2.93	1.90	3.20	4.97

INFLUENCE OF THE SUPPLY OF ASH ELEMENTS ON THEIR PERCENTAGE CONTENT IN THE MILK.

In Table V are displayed results showing the effect of a wide variation in the intake of ash elements on the percentage of these constituents in the milk.

This table emphasizes the constancy of composition of the milk in respect to the ash elements, even when a wide variation in intake of these elements prevailed. The form of intake of phosphorus, magnesium and potassium, whether as phytates, sulphates, or chlorides, appeared to have no influence on the amounts secreted by the mammary cells.

TABLE V.—PERCENTAGES OF PHOSPHORUS, CALCIUM, MAGNESIUM AND POTASSIUM IN THE MILK.

DATE.	TOTAL ASH MATERIAL FED.				IN MILK.			
	P_2O_5	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O
	grams	grams	grams	grams	Per ct.	Per ct.	Per ct.	Per ct.
December 3....	190.5	23.5	65.4	152.6	0.178	0.135	0.019	0.193
" 4....	190.5	23.5	65.4	152.6	.172	.136	.018	.191
" 5....	161.4	23.9	55.7	138.0	.172	.130	.020	.181
" 7....	103.5	24.7	39.3	108.9	.171	.132	.018	.190
" 9....	46.7	26.0	22.5	80.4	.175	.131	015	.165
" 15....	46.7	26.0	22.5	80.4	.168	.128	.017	.170
" 21....	46.7	26.0	22.5	80.4	.168	.125	.013	.148
" 22....	46.7	26.0	22.5	80.4	.178	.130	.017	.154
" 29....	190.5	23.5	65.4	152.6	.164	.125	.016	.157
" 30....	46.7	26.0	61.9	153.3	.172	.128	.020	.146
February 5....	190.5	23.5	65.4	152.6	.178	.118	.019	.175
" 6....	46.7	26.0	22.5	152.3	.180	.118	.018	.185

INFLUENCE OF THE SUPPLY OF ASH ELEMENTS ON THE YIELD OF MILK SOLIDS AND THE EXCRETION OF URINE.

To show the effect of the supply of phosphorus, magnesium and potassium, as phytin, sulphates or chlorides on the flow of milk and the volume of urine excreted, periods of short duration were selected, representing adjusted conditions of the animal to the ration.

There is nothing in the data presented that indicates with this animal a constant relation between the amounts or form of the ash elements injested in the ration and the amount of milk, or quantity of solids produced. Even when we consider a transition period involving the gradual withdrawal of phytin, there was no effect on the volume of milk produced. On December 4 with a high phytin ration, the amount of milk secreted was 16,889 grams, while on December 9 or at the termination of the transition period, and corresponding to the lowest intake of phytin, the milk flow was 17,025 grams.

The consistent and pronounced effect of the supply of phytin (December 1 to 4), of potassium and magnesium as chlorides and sulphates (January 6 to 9), of potassium alone, as a chloride (February 25 to 28), or of potassium as a phytate (March 13 to 16) on the volume of urine produced daily is striking, when compared with the low intake of the ash elements recorded in the other periods. When this effect is considered in relation to the daily water consumption, there is seen to be no close paral-

lelism. However, the proportion of water excreted through the urinary tract is normally in herbivora such a small proportion of the total intake, that fluctuations amounting to 10 pounds in the daily consumption affected the volume of urine produced but slightly. (See period February 25 to 28 and March 13 to 16.)

It appears from this experiment that the volume of urine produced was not so closely related to the amount of water consumed, as it was to the quantity and form of the ash elements in the food. A glance at Table V also shows the pronounced variation in the percentage composition of the urine, with respect at least to calcium and potassium. This will be discussed later.

TABLE VI.—EFFECT OF SUPPLY OF BRAN ASH CONSTITUENTS AND ADDED SALTS ON YIELD OF MILK AND MILK SOLIDS AND EXCRETION AND COMPOSITION OF URINE.

Date.	Fed daily.				Yield of milk daily.	Milk solids. daily.			Yield of urine daily.	Water drunk daily.	In Urine.			
	P_2O_5	CaO	MgO	K_2O		Casein.	Fat.	Solids.			P_2O_5	CaO	MgO	K_2O
	gms	gms.	gms	gms.	grams.	gms.	gms.	grams.	grams	lbs.	per ct	per. ct.	per. ct	per. ct
Dec. 1-4.....	190	23	65.0	152	17,467	340	515	1,860	7,342	116.6	0.008	0.009	0.10	0.96
" 19-20...	46	25	22.0	80	16,162	328	464	1,737	4,196	121.2	.011	.18	.06	.42
Jan. 6-9......	46	26	62.0	153	13,961	282	418	1,506	8,729	133.6	.008	.10	05	1.14
" 28-31 ...	42	22	18.7	78	14,051	295	431	1,[illegible]73	4,502	102.5	.006	.21	.07	.18
Feb. 25-28....	46	26	22.0	153	13,223	....	....	......	8,431	116.9	......	......	......	.....
Mar. 13-16...	81	25	22.0	126	12,723	....	....	......	7,034	126.4	......	......	......	.....

The data embodied in Table VII emphasize and extend what has previously been shown to be true with other animals, namely, that the nitrogen and phosphorus excretion have no close, direct relation to each other. This is equally true in respect to potassium and magnesium, which rose and fell in the amounts excreted with great regularity and dependent on the amounts ingested. Of course at no time was the animal starving for potassium or magnesium and this interpretation applies only when the supply was still considerably above the animal's requirements. In the case of lime the supply was a constant one, consequently affording no data on this point. That there is a definite and more or less constant metabolism of the ash elements of the cell which bears a definite relation to the amounts of nitrogen suffering degradation in cellular metabolism is entirely possible.

TABLE VII.—RELATION BETWEEN THE NITROGEN AND ASH EXCRETION.

Date.	N.		P_2O_5		CaO		MgO.		K_2O.	
	Fed.	Outgo	Fed.	Outgo	Fed.	Outgo	Fed.	Outgo	Fed.	Outgo
	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
Dec. 1-4........	286	300	190	181	23.5	50.0	65.4	68	153	168
" 19-22.....	283	263	47	67	26.0	56.0	22.0	18	80	77
Feb. 10-13.....	283	275	47	58	26.0	61.9	22.0	13	253	126

PHYSIOLOGICAL EFFECT OF THE VARIOUS RATIONS ON THE CHARACTER OF THE FECES AND ON THE OESTRUM PERIODS.

Abundant additional proof of the laxative effect of phytin was accumulated. Even when the amount of crude fiber incident to a large consumption of washed bran was reduced in quantity and a sudden change was made from a whole bran ration to one with an equivalent quantity of crude fiber, but without phytin, constipation resulted. When the washed bran ration was supplemented with a quantity of magnesium and potassium, as chlorides and sulphates, equivalent to these bases, removed in the washing process, a sudden change from the whole bran to the washed bran ration could be made without in any way modifying the character of the feces. They remained normal and soft. When the substitution for the removed bases was confined to potassium alone, either as a sulphate, or chloride, and the change from the whole bran ration to one of washed bran was made, the character of the feces was invariably changed. While constipation did not result, the feces became drier and firmer. When potassium was supplied as a phytate to a washed bran ration, the character of the feces was normal and soft.

It is interesting in this connection to record the fact that the difference in the percentage of moisture in feces appearing normally dry and formed, and those of a softer character, was not so large as we supposed. A so-called dry and formed excreta contained 83.5 to 84.5 per cent water, while one produced during a laxative condition contained 87 to 89 per cent water. No disturbance of the oestrum periods was observed.

BALANCE OF INCOME AND OUTGO OF PHOSPHORUS AND THE ASH ELEMENTS AND THEIR CHANNELS OF EXCRETION.

The data embodied in Table VIII cover those parts of the periods in which it was believed that the animal had reached an adjusted condition. In most cases averages for four days are given.

The constancy in the amounts of the ash elements secreted in the milk independent of the quantity and form ingested in the food, has already been mentioned.

The principal channel for the excretion of phosphorus and magnesium was the gut. Increased intake of these two elements raised their output in the urine, but generally the proportion was relatively small. The form of intake of magnesium did not materially affect the path of output.

There was also a constant excretion of calcium through the gut, this being the main channel for this element. However, in periods of low phosphorus intake, there was a considerably increased output of this element in the urine. At no time in the experiment was the intake of calcium equivalent to the output.

Potassium was eliminated by both the urinary and intestinal tracts. The amounts of potassium eliminated through the gut appears to bear a close relation to the amounts of ingested phosphorus. A high intake of potassium accompanied by a high amount of phosphorus increased the elimination by the gut. During the later periods of the experiment there appeared to be a storage of magnesium and phosphorus, especially the latter, at periods of high intake of this element.

GENERAL DISCUSSION OF THE EXPERIMENT.

The data obtained from this experiment covered daily observations of 3½ months. At no time was the appetite of the animal impaired. She remained strong and vigorous throughout the period. She also maintained her body weight. One of the most striking facts brought out was the constancy in ash content of the milk, in spite of the considerable fluctuation in the amounts ingested in the food in the various periods. This is not so surprising, however, when we remember the constantly accumulating evidence that the animal secretions are elaborated quite independent of a considerable variation in the character of the food. The effect of withdrawal of phytin on fat elaboration in the milk was not apparent.

TABLE VIII.—INCOME AND OUTGO OF ASH ELEMENTS.

DATE.	FEED.	INTAKE.				OUTPUT IN MILK.				OUTPUT IN FECES.				OUTPUT IN URINE.				TOTAL OUTPUT.			
		P_2O_5	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O
		gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
Dec. 1-4......	Whole bran...	190.5	23.5	65.4	[illegible]	30.4	23.2	3.4	[illegible]	150.5	24.5	57.2	64.4	0.63	0.64	7.3	70.8	181.5	48.3	68.0	168.8
" 19-22....	Washed bran.	46.7	26.0	22.5	80.4	27.6	19.8	2.6	26.6	39.5	28.3	12.7	31.9	.47	7.80	2.8	8.4	67.6	55.9	18.1	76.9
" 27-28....	Whole bran...	190.5	23.5	65.5	152.6	27.6	19.5	2.7	24.0	145.3	30.5	59.9	57.5	2.30	.29	3.0	86.6	175.2	50.3	65.6	168.1
Jan. 6-9.....	Washed bran. $MgCl_2$ K_2SO_4	47.7	26.0	61.9	153.6	23.4	18.2	2.7	22.3	36.2	25.0	41.6	29.2	.67	8.40	4.5	98.9	60.3	51.6	48.8	150.4
" 18-19....	Whole bran...	190.5	23.5	65.4	152.6	23.5	17.5	2.8	22.3	126.3	21.8	46.9	57.9	5.20	1.00	4.3	56.7	155.0	40.3	54.0	137.4
" 28-31....	Washed bran. Starch.	41.5	21.5	18.7	78.1	24.1	18.5	2.6	23.4	30.4	21.2	8.1	27.6	.27	9.70	3.1	8.4	55.4	49.4	13.8	59.4
Feb. 5........	Whole bran...	190.5	23.5	65.4	153.3	24.7	16.4	2.6	23.0	120.9	18.3	42.3	11.6	20.00	.45	11.2	24.6	65.6	35.1	56.1	159.2
" 10-13...	Washed bran. K_2SO_4.	46.7	26.0	22.5	152.6	26.4	19.4	2.7	25.6	[illegible]	[illegible]	7.7	28.7	.64	5.80	2.9	71.9	58.0	44.6	13.3	126.2
" 17......	Whole bran...	190.5	23.5	65.4	[illegible]	23.4	16.7	2.4	22.1	77.5	20.1	38.9	22.8	......	......	......	......	......	......	......	......
" 25-28....	Washed bran. KCl.	46.7	26.0	22.5	153.0	23.1	16.5	2.4	22.0	26.5	19.2	16.5	[illegible]	......	......	......	......	......	......	......	......
Mar. 13-16...	Washed bran. K Phytate.	80.6	26.0	22.5	[illegible]	22.2	15.9	2.3	20.9	32.4	22.8	23.2	39.8	......	......	......	......	......	......	......	......

There was also no quantitative disturbance in the production of the other organic constituents of the milk incident to the withdrawal of phytin. From this it appears that when such disturbances have been produced, as in previous experiments, they must be considered as individualistic, but that we do not have in the body phytin a specific chemical entity directly regulating and imperatively concerned in the process of fat production. It is, of course, not here questioned that the components supplied by phytin are important sources for the ash constituents in the animal's metabolism.

With this animal there was also no disturbance in the flow of milk consequent upon the withdrawal of phytin, or any other supplied salts.

The flow of urine was directly related to the supply of phytin, as well as to certain of its components, when these were supplied as salts in the ration. This was equally manifested when the displaced phytin was substituted by potassium and magnesium as sulphates and chlorides, or by potassium alone as a chloride or phytate. The increased output of potassium in the urine, which always accompanied an increased intake, strongly suggests a close relation between the diuresis produced with the whole bran and its high potassium content. The percentage of potassium in the urine, however, does not remain constant, even with increased flow. When the volume increased, the percentage of potassium often rose to 1 per cent, while in the period of low output it was but one-tenth that amount.

The constipating effect incident to withdrawal of phytin was always manifest. When, however, the phytin was replaced with magnesium sulphate, a laxative effect was produced, but when this substitution was made with potassium sulphate or chloride, an unmistakable dryness of the feces resulted. Again, when the displaced natural phytin was substituted by a prepared potassium phytate, a laxative condition resulted. A glance at Table VIII will reveal the fact that the principal channel of excretion of magnesium in the cow is the gut. The inference from a consideration of the facts lends strong color to the theory that the phosphorus and magnesium carried by whole wheat bran are largely responsible for this action. It is a fact that when the washed bran was supplemented with crude phytin, the excretion of magnesium in the gut was increased.

The lime supply in the ration of the entire period was manifestly deficient. The output was approximately 50 grams daily, while the intake was but 25 grams. The popular notion that wheat bran is particularly useful as a building material for growing animals, due to high ash content, needs qualification. It is high in total ash, but its content of lime is relatively low. Ten pounds of wheat bran supplied but eight grams of calcium oxide.

This period of feeding covered 110 days and consequently entailed an approximate loss of 2,500 grams, or 5½ pounds of lime. Data from the Rothamsted Experiment Station on the ash constituents of various animals affords an approximate estimate of the total lime in our animal. At the beginning of the experiment it was about 24.2 pounds. This means that during the period of our experiment there had been a loss of about 25 per cent of the entire lime content of the animal. A certain and definite percentage content had been maintained in the milk, and an apparent waste, possibly indicating general cell metabolism, had been excreted in the feces and urine. This large loss above that used for milk production could have had no other source than the skeleton.

These data support what our experiments with pigs have shown, namely that the skeletal tissue can vary its ash content within quite wide limits, thereby acting as a source of supply over considerable periods of time for certain ash constituents that may be deficient in quantity in the food. During the periods of high phosphorus feeding, there appeared to be a storage of phosphorus and especially of magnesium. This condition prevailed more particularly during the later periods of the experiment. This would make clear how it was possible to withdraw the needed supply of lime from a calcium-phosphorus complex, and still retain the phosphorus. However, it is also possible that the constant withdrawal of lime did not involve the calcium phosphate of the skeleton, but that the calcium carbonate, which is also supposed to be present, was involved in this interchange; but this is mere supposition.

During periods of low phosphorus feeding there was constantly an increased output of calcium in the urine, apparently again involving the metabolism of a calcium-phosphorus entity. The total output of calcium was greater during these periods

than during periods of high phosphorus feeding. It is apparent from the data that the daily loss of calcium-oxide due to milk production and cell metabolism was at least 50 grams. The animal weighed 1,150 pounds and produced about 30 pounds of milk daily.

The periods of low phosphorus feeding also afford data on the output of this element at periods of phosphorus starvation. The average amount of phosphorus pentoxide lost daily through the milk and cell metabolism was approximately 60 grams. It is an interesting fact that in spite of deficient supplies of these two elements during considerable periods there was nevertheless an apparent waste. A part was constantly being metabolized and passed out of the reach of the reconstructive processes. Whether this means that the form, in which the ash elements are presented to the cell before metabolism, is different from that existing after such processes have occurred, is, of course, unknown.

The supply of magnesium and potassium compounds in the food at all periods was equal to or greater than that excreted.

CONCLUSIONS.

1. A high potassium intake accompanied by a high phosphorus intake gave a high potassium content in the feces, although a considerable portion of potassium was also excreted in the urine.

2. A high potassium intake accompanied by a low phosphorus intake gave a low potassium content in the feces, with a high output of this element in the urine.

3. A high potassium intake accompanied by a low phosphorus and high magnesium intakes gave a high potassium output in the urine.

4. Magnesium when supplied as a chloride or as a phytate was largely excreted in the gut.

5. Phosphorus and calcium were also principally eliminated by this channel.

6. A low phosphorus intake was accompanied by a high calcium output in the urine.

7. A deficient calcium intake was nevertheless accompanied by a considerable output of this element in the gut. This statement is also true of phosphorus.

8. When calcium or phosphorus were deficient in quantity in the food, the skeletal tissues appeared to be ready sources of supply. The average quantities of calcium oxide and phosphorus pentoxide metabolized and excreted daily by this animal during periods of deficient supply were respectively 50 and 60 grams.

9. The supplies of potassium and magnesium were in all periods equal to or above the amounts eliminated.

10. Variations within wide limits in the form and quantity of supply of potassium, magnesium, or phosphorus, did not influence the percentage content of these elements in the milk.

11. With this animal there was no appreciable fluctuation in the percentage of organic constituents in the milk relative to the supply of phytin.

12. Marked diuresis was produced by the quantity of phytin supplied. A high potassium and magnesium intake as sulphate and chloride, produced a similar effect, as did potassium alone when supplied as a chloride. This would indicate that the high potassium intake accompanying the whole bran rations was responsible for this phenomenon.

13. A sudden withdrawal of phytin produced constipation. This was even manifested when the intake of crude fiber was reduced to that of normal bran.

14. The laxative action is more easily understood when it is remembered that the channel of excretion of phosphorus, calcium and magnesium especially, and a part of the potassium, when supplied in wheat bran, is by way of the gut.

15. The "margin of safety" provided in the skeletal tissues in the animal precludes against immediate disastrous results consequent on a sudden deficit in the intake of phosphorus or calcium.

Bacterial Content of the Milk of Individual Animals

E. G. HASTINGS AND C. HOFFMANN[1]

The presence of bacteria in the udders of cows has been shown by direct examination of the tissue from various parts of the mammary gland. That some bacterial growth takes place in the udder is also shown by the fact that milk, drawn under such conditions as to exclude all other sources of bacteria, nearly always contains the organisms in greater or less numbers. Ward[2] states that the number may vary from 200 per cc. of the milk to 900 per cc., the average being about 500 per cc. A dairyman cannot hope to produce milk with a lower germ content, no matter how careful he may be, as this represents the contamination coming from the interior of the udder. The rejection of the first milk drawn, as practiced in many dairies, has no appreciable effect in reducing the germ content of the entire quantity of milk drawn at a milking.

Repeated examinations of the milk of an animal have shown that the same organisms may persist in the udder for years. Ward cites an instance in which an organism indistinguishable from *Streptococcus pyogenes* was found in the udder of an animal during a period of two and a half years.

The supposition has also been expressed that not only may the same organisms persist in the udder for long periods, but also that they may be found in very considerable numbers. Statements have also been made that in those dairies where an attempt is made to produce milk of the lowest possible bacterial content, attention should be paid to the bacterial content of the udders of the individual animals. Esten[3] states, "The bac-

1 Formerly Assistant in Bacteriology.
2 Pure Milk and the Public Health, 1909, p. 4.
3 Conn. (Storrs) Agr. Expt. Sta. Bul. 51.

terial content of the udder of a cow is an important factor and one that determines the value of a cow in producing healthful market milk.'' So far as the writers are aware no data have been published that would form a basis for such statements, as mentioned above.

SCOPE OF THIS INVESTIGATION

In connection with other work, a large number of determinations of the germ content of the milk of individual animals of the University herd have been made. The results obtained with a number of animals are worthy of especial mention.

BACTERIOLOGICAL METHODS EMPLOYED.—The method used to determine the number of bacteria in the various samples was to prepare plate cultures of the milk soon after it was drawn from the cow. The culture medium employed was agar having an acidity of 1. per cent (Massachusetts scale) and containing 1 per cent of lactose. The plates were counted after 48 hours incubation at 37 degrees C. It will be seen that the methods employed are identical with those used in the examination of many certified milks. The samples of milk were drawn under such conditions as to exclude, in large part, contamination from all external sources.

RESULTS OBTAINED.—Two animals were found in the herd whose milk constantly contained large numbers of bacteria. The data collected in the case of these two animals are presented in this paper, together with the results obtained from the examinations of the milk of a third animal, whose milk constantly showed small numbers of bacteria. It will be noted from the tables presented that many of the samples from these animals were taken on the same days and were thus exposed to the same external sources of contamination. The samples were also plated on the same medium. No doubt can thus remain concerning the original source of the bacteria found in the samples.

BACTERIAL CONTENT OF MILK OF THREE COWS

In Table I are presented the data obtained from the examination of the milk of Brownie. The figures from December 10, 1906, to March 28, 1907, inclusive, refer to one lactation period, the remainder to another, as the animal calved on August 13, 1907.

TABLE I.—BACTERIAL CONTENT OF THE MILK OF BROWNIE

Date.	Bacteria per cc.	Date.	Bacteria per cc.
1906.		1907.	
Dec. 10	14,500	Oct. 20	64,000
" 11	19,900	" 22	66,700
" 12	8,600	" 23	11,900
" 13	15,100	" 24	305,000
" 14	25,400	" 25	34,300
		" 28	48,100
1907.		" 29	23,300
Jan. 6	23,300	" 30	12,900
" 7	11,500	Nov. 1	41,900
" 8	5,200	" 5	10,900
" 14	13,400	" 13	18,200
" 16	4,100	" 24	108,000
" 17	11,000	" 29	56,000
" 20	23,200	Dec. 2	12,000
" 21	18,800	" 6	15,000
" 22	100,700	" 19	13,000
Feb. 7	4,200	" 21	13,500
" 12	36,000		
March 5	2,000	1908.	
" 20	28,000	Jan. 6	4,500
" 22	1,700	" 8	7,000
" 27	14,500	" 11	36,000
" 28	59,000	" 13	34,000
Sept. 17	14,100	" 16	36,000
" 18	14,100	" 17	10,000
" 19	23,100	" 18	66,000
" 21	16,100	" 23	45,000
" 24	12,300	" 24	7,000
" 25	16,000	" 31	9,000
" 26	13,800	Feb. 3	72,000
Oct. 1	18,800	" 27	15,000
" 2	5,400	" 28	87,000
" 3	35,700		

During the entire period the animal was apparently healthy and did not suffer from any attack of garget, which might have been accompanied by a high germ content. The only abnormality of the animal was a constant leaking of the milk from one hind quarter. Various workers have expressed the idea that such animals show a high germ content in the milk from the leaky quarters. Accordingly a number of determinations of the bacterial content of the milk from the different quarters of this animal were made, but no marked or constant difference could be detected between the leaking and non-leaking quarters.

The samples from December 10, 1906, to October 20, 1907, were taken from the pail at the end of the milking, and represent the entire amount of milk drawn. The remainder were taken at the middle of the milking by drawing a few streams from each teat into a sterile flask.

The period covered by these examinations was 15 months, and included portions of two lactation periods. But 11 of the 61 samples examined contained less than 10,000 bacteria per cc.,

thus were above the standard set for certified milk. The average of all determinations was 30,700 per cc.

The organism which comprised 90 per cent or over of the total germ content, in the major part of the samples, was a streptococcus, very similar to *Streptococcus pyogenes* in morphology, as well as in its bio-chemical reactions. The animal had had no recent attack of garget, none having been noted in the two lactation periods included in the interval during which the examinations were made, so that this unusually high germ content must be regarded as a normal condition.

TABLE II.—BACTERIAL CONTENT OF THE MILK OF DORINE.

Date.	Bacteria per cc.	Date.	Bacteria per cc.
1907.		1907.	
Feb. 11	3,500,000	Sept. 21	27,700
" 13	3,100	" 24	5,900
" 18	33,000	" 25	16,400
March 18	70,000	" 26	33,300
" 22	1,370,000	Oct. 1	14,700
" 26	130,000	" 2	7,700
" 28	130,000	" 3	5,900
Aug. 16	56,500	" 22	154,000
" 21	126,000	" 23	137,000
" 27	26,300	" 24	35,600
" 30	65,200	" 25	24,700
Sept. 4	2,500	" 28	55,700
" 5	21,800	" 29	50,300
" 17	59,000	" 30	43,400
" 18	11,300	Nov. 1	27,800
" 19	14,120	" 5	36,300
" 20	14,600		

In Table II are given the results obtained from the examination of the milk of Dorine, an animal which so far as was known had had no attack of garget and was normal in every respect. The observations which extended over nine months, refer to a single lactation period. This animal was milked during a portion of the time by the milking machine. The samples in all cases represent the entire amount of milk drawn at each particular milking.

Of the 33 determinations made, but five fall below 10,000 bacteria per cc. Excluding the two determinations of February 11, and March 22, which were exceedingly high, the average germ content per cc. is 38,800 or considerably in excess of the animal previously noted. The high germ content was due almost wholly to the large numbers of a streptococcus, similar if not identical with that found in the milk of Brownie.

TABLE III.—BACTERIAL CONTENT OF THE MILK OF MERNEY.

Date.	Bacteria per cc.	Date.	Bacteria per cc.
1906.		1907.	
Dec. 14	2,480	Nov. 1	2,810
" 18	1,080	" 5	290
" 19	1,320	" 13	4,250
1907.		1908.	
Jan. 6	110		
Sept. 20	1,700	March 2	170
" 21	170	" 6	70
Oct. 3	270	" 12	100
" 22	110	" 14	50
" 23	180	" 20	150
" 24	160	" 26	1,080
" 25	310	" 28	130
" 28	2,900	April 3	130
" 29	420	" 4	350
" 30	1,000	" 11	80

The data collected from the examination of the milk of a third cow, Merney, is given in Table III. This animal was perfectly normal in all respects. The observations were all included in a single lactation period. It will be noted that the time covered is much the same as in the case of the other animals. The samples previous to March 2, 1908, were of the entire milk drawn at a single milking. The remainder were taken at the middle of the milking in a sterile flask.

On the 27 determinations made, not one exceeded 5,000 bacteria per cc., the average of all analyses being but 800 bacteria per cc., as compared to 38,800 in the case of Dorine, and 30,700 for the milk drawn from Brownie.

BACTERIAL CONTENT OF THE MILK OF A HERD

A large number of determinations were made of the milk of the other animals in the herd. None of 30 other animals approximate the figures given for Dorine and Brownie. There is good reason to believe that the average bacterial content of the milk as it is drawn from the udders of healthy cows is not over 1,000 per cc. If this be taken as a basis for calculation and one such animal as Dorine be found for each 16 cows, the proportion found in the University herd, the average bacterial content of the milk will be trebled, due to the presence of this one animal among the 16.

The presence of such animals in the herd is probably of little practical significance in ordinary dairying. In cases of certified

and sanitary dairies, attempting to produce milk with the lowest possible germ content, such animals will be of importance since they will raise markedly the average bacterial content of the milk of the herd, as it is determined by the plate cultures of the bacteriologist. It would thus seem that attention may well be paid by the managers of certified dairies to the bacterial content of the udders of individual cows purchased for the dairy.

TYPES OF BACTERIA FOUND

In the case of two animals, Brownie and Dorine, the high number of bacteria was due largely to the presence of a single kind of organism, a streptococcus, which would be called *Streptococcus pyogenes* when found in the microscopical examination of milk sediments. Its detection in the milk of a single cow might lead to the demand that the milk of such an animal be rejected. As far as could be determined the milk of the animals in question was normal, and to be considered as healthful milk. The same organism has also been found in the milk of other animals, at times in large numbers, although no evidence of udder trouble could be detected. Rühms[4] has fed milk containing streptococci to various young animals. No injurious effect was to be noted. It would not seem justifiable to call all bacteria that appear in milk sediments in chains of cocci, pyogenic organisms.

In the case of the third animal, Merney, the bacterial content of the milk was almost exclusively made up of yellow and white cocci. These types of bacteria have been found by numerous investigators to be the predominating ones in the udders of cows. They make up the major part of the germ content of fresh milk and of milk drawn under very clean conditions. If the analyst finds them predominating on his plates, he may be certain the milk, if it is of any age, was drawn under sanitary conditions, for otherwise the numbers of bacteria coming from other sources will be so large that the udder forms will be difficult or impossible to find, as, for instance, in ordinary market milk.

---

[4] Abs., Centbl. Bakt. (etc.), 2 Abt., 1909, **22**: 136.

LEUCOCYTE CONTENT OF MILK

During the interval covered by the examinations detailed, frequent determinations of the leucocyte content of the milk of the individual animals were made. In Table IV is presented a summary of the leucocyte content of the milk of the three animals.

It will be seen that the animals, whose milk contained large numbers of bacteria, were the ones showing an abnormally high leucocyte content in the milk. A long series of determinations of the leucocyte content of the milk of each animal in the herd was made.[5] Brownie and Dorine were the animals whose milk showed the highest number, while Merney was among those whose milk was low in leucocytes.

TABLE IV.—LEUCOCYTE CONTENT OF MILK OF THREE COWS.

	No. of tests.	Leucocytes per cc.		Per cent of samples examined that fell within following limits.				
		Minimum number.	Maximum number.	50,000 or below.	50,000 to 100,000	100,000 to 500,000	500,000 to 1,000,000	1,000,000 or above.
Dorine.....	63	126,200	1,966,000	0	0	38	49	13
Brownie ..	66	122,500	1,781,000	0	0	64	30	6
Merney ...	11	30,400	288,000	36	18	46	0	0

A careful physical examination of the udders of the animals was made by the Station Veterinarian. In the case of Brownie there was a slight induration in one quarter of the udder, which may have been caused by an attack of garget. The udders of the other two animals were normal. As far as is known these animals have never had any udder trouble.

Whether the high number of leucocytes is due to the presence in the udder of large numbers of organisms resembling *Streptococcus pyogenes* is a question that cannot be answered at the present time. It is possible that Brownie and Dorine have had, at some previous time, an attack of garget caused by pyogenic bacteria, and that the organisms persisted after recovery. In other words, cows are possibly able to become "carriers of bacteria" after attacks of contagious garget, just as human beings become "carriers" of typhoid.

[5] Wis. Agr. Expt. Sta., 24th Ann. Rpt., p. 231.

CONCLUSIONS

The same organisms may not only persist in the udder of a cow for long periods, but may be present constantly in large numbers.

In sanitary dairies the normal content of the udders of the individual animals may well be taken into account.

The Occurrence and Distribution of a Lactic Acid Organism Resembling the *Bacillus Bulgaricus* of Yogurt

E. G HASTINGS AND B. W. HAMMER[1]

The importance of the lactic acid fermentations has long been recognized and the various organisms causing these fermentations of milk have been studied in detail. Within the last few years attention has been directed, on account of the work of Metchnikoff, to a supposedly new group of bacteria causing an acid fermentation of milk. In brief, this group of organisms is characterized by their ability to produce much larger amounts of acid in milk than are ever formed by the ordinary types of acid-forming bacteria, such as *B. lactis acidi,* or *B. coli communis;* by their high optimum temperature for growth, and the limited conditions under which they will grow on nutrient media. Metchnikoff[2] recommends fermented milk as a common article of diet, and especially that milk fermented by the organism found in the Bulgarian fermented milk "Yogurt."

Due to the ideas of Metchnikoff concerning the therapeutic value of milk fermented by this organism, fermented milks have been widely introduced into this country and abroad. They were sold under various names, and are claimed to contain the organism characteristic of Yogurt, *B. Bulgaricus.* It has been held that the value of the fermented milk was due to this organism rather than to its acid content. Following this idea various firms have put tablets on the market supposedly containing the organism which are to be used by people that cannot take the fermented milk.

---

[1] Formerly Assistant in Bacteriology.
[2] Prolongation of Life, 1908, p. 161.

It has been supposed that this organism was characteristic of, and confined to, the Bulgarian fermented milk. Kuntze[3] has indicated that the acid forming organisms found in such fermented drinks as the Matzoon of Armenia, the Gioddu of Sardenia, and the Leben of Egypt are similar to *B. Bulgaricus.* As far as the writers are aware no one has supposed that similar organisms were commonly found in milk.

MAXIMUM ACIDITY DEVELOPED IN MILK.

The maximum degree of acidity developed in the spontaneous souring of milk is usually stated as ranging from 1 to 1.25 per cent. This is similar in amount to that produced by pure cultures of acid-forming bacteria of the group represented by *B. lactis acidi.*[4]

There are, however, scattered through the literature, statements concerning much higher degrees of acidity which have been noted in milk. Boutroux[5] in studying the acid fermentation of milk found that in a solution containing albuminous matter and glucose 1.5 per cent of acid was formed. Richet[6] found that milk kept at 40 degrees C. developed 1.6 per cent of acid, while if gastric juice was added to the milk as much as 4 per cent of acid might be formed in a few days. Whey developed not more than 1.6 per cent. Koning[7] in samples of market milk kept at 37 degrees C. for eight days noted an acidity of 2.35 per cent, in another sample kept five days at 37 degrees C. he found 2.51 per cent, while samples of the same milk kept at 22 degrees C. had developed in the same time but 0.9 per cent. Heinemann[8] in his studies on the significance of streptococci in milk, incubated samples of market milk at 37 degrees C. for eight days and found a maximum acidity of 3 per cent. Marshall[9] also noted abnormally high degrees of acidity and ascribed them to associative action of bacteria. Jensen[10] states that *B. casei* ϵ can produce 2.7 per cent of lactic acid.

---

[3] Centbl. Bakt. (etc.) 2, Abt., 1908, **21**: 737.
[4] Lafar, Handbuch der Technischen Mykologie, **2**: 54.
[5] Compte Rendu., Acad. Sci., **86**: 605.
[6] Ibid., **86**: 550.
[7] Milchw. Zentbl., 1905, **1**: 289.
[8] Jour. Infect. Diseases, 1906, **3**: 173.
[9] Centbl. Bakt., (etc.) 2, Abt., 1908, **21**: 57.
[10] Centbl. Bakt., (etc.) 2, Abt., 1904, **13**: 526.

It will thus be seen that there are organisms able to produce large quantities of acid in milk, and that they apparently are favored by high temperatures (Koning and Heinemann), agreeing in this respect with *B. Bulgaricus.* Von Freudenreich has found *B. casei* ε widely distributed in Swiss cheese, whey-rennet and in milk. As far as the writers are aware similar organisms have not been found elsewhere in market milk. The investigators noting the high acidity mentioned apparently made no effort to discover the cause.

In the course of other work, milk from various sources was placed in stoppered bottles and incubated at 37 degrees C. The acidity of the samples as determined after several days' incubation was so great as to attract attention, and an effort was made to determine the cause. The rate of increase of acidity in a sample of market milk, incubated at 37 degrees C. was as follows:

Period of Incubation	Per cent Acidity
1 day	1.03
2 days	1.10
3 "	1.22
4 "	1.35
7 "	2.25
150 "	2.60

During the past two years many samples of milk from the University creamery have been incubated under like conditions, and in every instance the results have been similar to those given. It was evident from a study of the rate of acid formation, that the initial rapid increase in 24 hours was due to the ordinary lactic organisms. At about 1 per cent acidity their growth stopped and the acidity then increased slowly. It was evident that the second phase of increase in acid must be due to other organisms that *B. lactis acidi.*

This supposition was confirmed by a microscopical examination of the milk at frequent intervals. At the end of 24 hours the predominating form was the lactic organism, *(B. lactis acidi).* With lengthened periods of incubation long slender cells began to appear, and increased in numbers with increasing acidity until they were the predominating form in the milk. The cause of the high acidity was thus apparently explained.

THE CAUSAL ORGANISMS.

ISOLATION.—Attempts at the isolation of the organism were at first unsuccessful, as upon the ordinary media the conditions are more favorable for the growth of *B. lactis acidi*, which still persists in large numbers in the milk, than for the organism in question.

By making repeated inoculations from milk with a high acidity, and allowing each portion of milk inoculated to develop the maximum degree of acidity before inoculating from it, the ordinary lactic organisms were gradually eliminated, and thus the disturbing factor in the isolation largely removed. Lactose fermenting yeasts may also prove to be a source of trouble as they find favorable conditions for growth in the acid milk.

MORPHOLOGY OF THE ORGANISM.—The organism causing the high acidity is a bacillus 1 to 3 micra in length and from 0.3 to 0.5 micra in diameter. A tendency to form short chains is frequently noted. In milks which have been incubated for a considerable period long threads which show no cell divisions, are found. The organism is non-motile and non-sporogenous. It stains with aqueous solutions, and is Gram positive. Preparations made from milk having a high degree of acidity and stained with methylene blue show large numbers of irregularly stained organisms. Preparations treated with Neisser's stain show granules similar to those found in the diphtheria bacillus.

CULTURAL CHARACTERS.—The growth on nutrient media has no characteristic features. The growth is meagre in gelatine, agar and bouillon, even when containing a fermentable sugar. The colonies on lactose-agar are very small, almost microscopic in size. In lactose and glucose-agar stab cultures, the medium becomes somewhat opaque due to the action of the acid on the agar. This clouding of the medium is rarely noted with ordinary types of lactic acid-forming bacteria, since the amount of acid produced is much less.

TEMPERATURE RELATIONS.—The optimum temperature for growth has not been determined. Growth has been noted at 50 degrees C. It is probable that the optimum temperature for growth is between 40 and 50 degrees C. Growth takes place at ordinary temperatures. The relative rate of increase of acidity in raw creamery milk at 20 and 37 degrees C. is shown in Table I.

TABLE I.—PER CENT OF ACID IN RAW MILK AT 20 AND 37 DEGREES C.

TEMPERATURE.	DAYS.					
	3	4	6	8	13	23
20 degrees C.......	1.08	1.13	1.17	1.53	2.34	4.09
37 degrees C.......	1.67	2.45	2.97	3.15	....	....

It will be noted that the growth at 20 degrees C. is slow, but that the amount of acid finally produced is very great, practically all the sugar of the milk being fermented.

RELATION TO OXYGEN.—Growth occurs either in the presence or absence of free oxygen.

BIOCHEMICAL CHARACTERISTICS.—The organism is able to ferment lactose, dextose, saccharose and mannit, producing acid but no gas from these sugars. The ability to produce large amounts of acid in sugar broths is also pronounced. An acidity, calculated as lactic, of 0.6 per cent has been found in lactose broth, and 0.77 per cent in glucose broth. The ordinary lactic bacteria or the colon organism produce in similar media much smaller amounts, rarely over 0.2 per cent. It has been shown repeatedly that these forms are unable to grow in the presence of free acid, and that the amount of acidity noted in any nutrient medium is dependent on the quantity of substances that will combine with the acid formed. Slight traces of free acid stop the growth. In milk the amount of acid is dependent on the content of casein and ash. The organism studied is not inhibited by free acid. The milk fermented by it gives a strong reaction with congo red.

The maximum degree of acidity noted in milk was slightly over 4 per cent, in whey 2.8 per cent. The rate of acid formation is always slow, never approximating the rapid increase of 0.15 per cent per hour shown by the ordinary lactic bacteria.

With pure cultures milk is curdled in 3 to 4 days at 37 degrees C. The curd is perfectly homogenous and shows no tendency to shrink and to express whey. As the acidity increases the curd loses its firm consistency and is easily broken up into such fine particles that days are required for the curd to settle. The appearance in litmus milk is similar to that produced by *B. lactis acidi*, reduction of the litmus in the lower layers of the milk taking place.

A considerable amount of casein is brought into solution through the continued action of the acid. The organism has no proteolytic properties that can be noted by the use of gelatin or milk-agar. There is, however, some true digestion of the protein constituents of the milk as is shown by the increase of soluble nitrogen. Flasks of milk were inoculated with a pure culture and incubated at 37 degrees C. for 150 days. Determinations of soluble nitrogen were then made by neutralizing the milk so as to precipitate any casein brought into solution by the acid, and boiling and filtering. The nitrogen was determined in the filtrate. The control milk contained 0.06 per cent of soluble nitrogen, the inoculated flask 0.22 per cent. A considerable amount of the protein material of the milk had been rendered soluble.

Freudenreich, in his studies on the rôle of acid-forming bacteria in the ripening of Emmenthaler cheese, found that the group of rod-shaped organisms that formed high amounts of acid in milk exerted a solvent effect on the nitrogenous constituents of the milk. Numerous attempts have been made, in this country and abroad, to confirm Freudenreich's results, but without success, and apparently because the investigators used *B. lactis acidi* rather than the type of organism employed by Freudenreich. The results obtained in the experiments herein described thus confirm those of the Swiss bacteriologist.

RESISTANCE TO DRYING.—The ability of the organism to resist desiccation was tested by drying on pieces of filter paper which were placed in sterile milk at intervals. No positive results were obtained after 19 days. The resistance to drying is thus found to be small as compared with that of *B. lactis acidi.*

DISTRIBUTION OF THE ORGANISM.

PRESENCE IN MILK.—An effort has been made to determine whether the organism is widely distributed and occurs commonly in milk and other dairy products, or whether it is confined to the supply of the creamery where it was first found, and in the milk supply in which it is constantly present. At a milk exhibit held at one of the county fairs 16 samples of milk from separate farms were taken. The presence of the organism was determined by acidity tests of the milk after incubation at 37 degrees C. The farms had no connection with each other

through the return of whey and skim milk in the milk cans, as do those that send milk to a creamery or cheese factory, and accordingly no opportunity was offered for the organism to pass from one farm to another. The amount of acid developed in these samples of milk is shown in Table II.

TABLE II.—ACID DEVELOPMENT IN MILK FROM SEPARATE FARMS.

SAMPLE.	PER CENT OF ACID AFTER INCUBATION.		Sample.	PER CENT OF ACID AFTER INCUBATION.	
	13 days.	28 days.		13 days.	28 days.
1	2.6	2.8	9	0.8	1.1
2	1.5	2.1	10	1.4	1.7
3	1.4	1.7	11	1.4	1.8
4	1.2	1.5	12	2.5	2.7
5	2.6	2.5	13	2.2	2.5
6	2.5	2.7	14	2.6	2.6
7	1.4	1.8	15	1.2	2.0
8	3.0	3.0	16	2.6	2.8

Microscopical examinations made of samples 8 and 16 at the end of the incubation period showed numerous bacilli, while sample 9 showed only the diplococcus forms characteristic of the ordinary type of lactic organisms.

A number of samples of milk produced on farms where the greatest care is exercised to prevent contamination of the milk were examined in a similar manner. The acid development noted in these samples is shown in Table III.

TABLE III.—ACID DEVELOPMENT IN SANITARY MILK INCUBATED AT 37 DEGREES C.

SAMPLE.	PER CENT OF ACID AFTER INCUBATION FOR DIFFERENT PERIODS.					
	2 days.	4 days.	8 days	10 days.	14 days.	23 days.
1	0.99	0.99	1.19	1.37	1.50	....
2	.99	.99	2.34	2.43	2.45	....
3	....	.20	1.22	....	....	3.30
4	....	.20	.27	1.21	2.00	....
5	....	....	2.15	....	....	....

It will be seen that all of the samples undoubtedly contained the organism. The variations in maximum acidity can not be accounted for. The same is also to be noted in Table II.

PRESENCE IN BUTTER AND CHEESE.—Butter and cheese from widely separated parts of the state were examined for the presence of the organism by inoculating flasks of sterile milk with the butter and cheese. The results of these examinations are shown in Tables IV and V.

TABLE IV.—ACID DEVELOPMENT IN MILK INOCULATED WITH CHEESE.

Sample.	Per cent of acid after incubation for		Sample.	Per cent of acid after incubation for	
	14 days.	26 days.		14 days.	26 days.
1	1.5	1.9	5	2.3	2.50
2	1.9	2.3	6	2.5	*0.75
3	2.1	2.3	7	2.0	*0.46
4	2.7	2.8	8	2.5	2.80

* There was a reduction of acidity in case of samples 6 and 7, due to the growth of mold on the surface of the milk.

TABLE V.—ACID DEVELOPMENT IN MILK INOCULATED WITH BUTTER.

Sample.	Per cent of acid after incubation for		Sample.	Per cent of acid after incubation for	
	14 days.	26 days.		14 days.	26 days.
1	1.1	1.5	3	2.5	2.5
2	2.7	2.9	4	2.6	2.5

A sample of milk received from the Cornell University creamery developed an acidity of 2.8 per cent. A sample of sterile milk inoculated with a drop of raw milk in 1902, when examined in 1909, showed an acidity of 2.25 per cent. It is thus certain that the organism is no recent acquisition and that it is widely distributed in milk.

In Conn's latest classification of dairy bacteria no such organism is described. It is evident that this class of bacteria, undoubtedly characteristic of milk, has eluded the search of American bacteriologists and to a great extent of European bacteriologists. The reason it has not been isolated from dairy products is that the methods employed are not such as to attract attention to it. Possibly many of the unsolved problems of dairy bacteriology will find their solution through modifications of present cultural technique.

IDENTITY WITH ORGANISMS STUDIED BY OTHERS

As was previously mentioned, a large amount of work has been done on the acid-forming bacteria of the Bulgarian fermented milk, Yogurt. Organisms with varying cultural differences have been found by different investigators. As a group they are characterized by their morphology, being bacilli which show granules in the cell when stained with methylene blue or Neisser's stain, and which are Gram positive. They are immotile, non-spore-bearing. They grow very poorly on nutrient gelatin, agar and bouillon. They grow best at temperatures above 40 degrees C. They ferment lactose, saccharose, and glucose, without gas production and are not inhibited by free acid. Almost all the sugar fermented appears as acid, especially lactic acid. In milk the casein is partially digested.

Freudenreich's description[11] of the rod-shaped organisms found in the whey-rennet of the Swiss cheese maker and in Emmenthaler cheese indicate that they belong to the same group of bacteria as *B. Bulgaricus*. *B. casei* ε, for example, does not grow on media containing no sugar. Its optimum temperature is 42 degrees C. Milk is curdled very slowly by pure cultures. It has a digestive action on casein, and produces large quantities of acid both in milk and in sugar media. Saccharose, glucose and mannit are fermented with acid production, but no gas is formed.

B. casei ε is immotile, forms no spores and is Gram positive. It will thus be seen that the general characteristics of *B. Bulgaricus*, of *B. casei* ε, and of the organism described in this paper are very similar and the organisms are undoubtedly to be looked upon as belonging to the same group.

B. casei ε is considered by the bacteriologists of the Swiss Experiment Station as one of the important organisms concerned in the ripening of the Emmenthaler Cheese. Pure cultures of this organism are sent out to the cheese factories of Switzerland, and the results in improving the quality of the product and in overcoming abnormal fermentations have been successful.

The significance of the group of organisms found so widely distributed in milk and other dairy products in this country is unknown: It seems doubtful whether they have any rôle in

---

[11] Landw. Jahrb. Schweiz, 1904, p. 525.

the ripening of cheddar cheese comparable to that they are supposed to play in Emmenthaler cheese.

On account of their wide distribution in dairy products there is constant opportunity for the digestive tract of man to become seeded with them. We have no evidence that they are to be found in human feces except when large numbers of them are ingested, as in the use of fermented milk. It is evident that the organisms is one that does not find favorable conditions for growth in the alimentary tract and thus will not be an important factor in the intestinal flora of man. It would also seem probable that the beneficial effect of milk fermented by them is due to its chemical composition and the physical condition of the casein, rather than to any proliferation of the organisms in the intestine. The opposite view has been held by Belonowsky.[12]

CONCLUSIONS.

Mixed milk when incubated at high temperatures develops a much greater acidity than can be accounted for by the growth of *B. lactis acidi.*

The casual organism is a bacillus closely related to *B. Bulgaricus,* the characteristic organism of Yogurt, and to *B. casei* ε of Freudenreich. The organism is widely distributed in milk, butter and cheese.

---

[12] Metchnikoff, Prolongation of Life, 1908, p. 170.

Experimental Leucocytosis in the Cow's Udder

CONRAD HOFFMANN

Previous investigations have indicated that there are many factors which may be influential in causing an increase in the leucocyte content of cow's milk. A change of milkers, a change in the ration of an animal, undue excitement, feeding the animal during the milking process, bathing the udder in cold water, all resulted in a marked increase in leucocytes. Any disturbance of the cow, however slight, apparently exerts a marked physiological effect upon the udder.

Russell and Hastings[1] produced decidedly gargety conditions when injecting cultures of various types of organisms into the udder in their studies on the persistence of these forms in the udder. Even sterile, neutral solutions produced marked changes. Cary,[2] in a paper read before the meeting of the American Veterinary Medical Association, asserted that the injection of a boric acid solution into the udder produced a milk free from bacteria and leucocytes.

TECHNIQUE OF THE EXPERIMENT

It was deemed advisable to make a careful study of the effect of injections of the udder with various solutions upon the leucocyte content of the milk drawn therefrom. For this purpose, two cows were employed. The solutions used were: 1, sterile distilled water, 2, sterile 0.6 per cent sodium chloride solution, 3, sterile 2 per cent boric acid solution, and 4, a culture of *B. prodigiosus*. These solutions were injected at blood heat so

[1] Wis. Agri. Expt. Sta., 21st Ann. Rpt., 1904, p. 164.
[2] Expt. Sta. Rec., 19: 199.

that the temperature factor could be eliminated in the study of the resulting udder changes.

Two quarters of the udder were usually injected with quantities ranging from 150 to 300 cc. The solutions were introduced into the udder by means of a milking tube connected with a large separatory funnel graduated so that the amounts introduced into the udder could be accurately determined. No pressure was applied, the injection depending entirely upon the action of gravity (difference in water level—15 to 18 inches). All utensils used in this procedure were carefully sterilized in an autoclave prior to use so as to avoid the introduction of all outside organisms which might cause inflammation. The entire udder was first bathed in luke-warm water and then treated with a 10 per cent solution of zenoleum, also at body temperature. The udder was then carefully wiped and dried before proceeding with the injection.

Leucocyte and bacterial determinations were made upon the milk, morning and night, for a period of several days prior to injection. To secure the milk in as sterile a condition as possible, the udder was always moistened, the hands washed, and the milk drawn from each individual quarter into a separate sterile 1-quart can. Plates were made as soon after withdrawal of the milk as possible. Usually two to three hours elapsed before this could be done. The leucocyte determinations were made at the same time according to the modified Doane-Buckley method described in a previous paper.[3] Injections of the sterile solutions were made about six hours after the morning milking had been completed, or about 11 A. M. The cow was again milked at 4 P. M., approximately five hours having elapsed since the injection.

Even in so short a time marked changes invariably occurred in the texture and appearance of the udder. Inflammation, characterized by swelling and fever, could usually be detected, being more marked in some cases than in others. By injecting but two quarters of the udder a comparison of the milk from these could be made with that drawn from those not so treated, and as the tables and figures reveal, the differences were most marked and characteristic.

---

[3] Wis. Expt. Sta., 24th Ann. Rpt., 1907, p. 231.

RESULTS OF EXPERIMENTS.

EXPERIMENT 1. The right front and left hind quarters were injected with 150 and 300 cc. respectively of sterile water. The other quarters were not injected. In Table I are given the results of the determinations of the number of leucocytes and bacteria per cc. of the milk of the separate quarters. The number of leucocytes is expressed in thousands per cc.

TABLE I.—EFFECT OF INJECTION OF THE UDDER WITH STERILE DISTILLED WATER ON LEUCOCYTE AND BACTERIAL CONTENT OF THE MILK. (Cow No. 1.)

DATE.	RIGHT FRONT QUARTER.		RIGHT HIND QUARTER.		LEFT FRONT QUARTER.		LEFT HIND QUARTER.	
	L. per cc.	B. per cc.	L. per cc.	B. per cc.	L. per cc.	B. per cc.	L. per cc.	B. per cc.
	Thousands.		Thousands.		Thousands.		Thousands.	
Dec. 2, P. M...	682	1,300	526	6,200	518	18,500	1,883	6,800
" 3, A. M...	529	77,000	587	60,200	491	14,400	712	15,600
" 4, A. M...	21,104	58,900	1,479	35,500	353	35,500	3 090	48,700
" 4, P. M...	957	1,400	1,[illegible]62	53,100	1,012	4,700	1,306	18,800
" 5, A. M...	932	17,100	557	17,400	945	26,700	2,818	16,300
" 5, M......	Sterile distilled water, 150 cc.		No injection.		No injection.		Sterile distilled water, 300 cc.	
" 5, P. M...	5,012	800	672	43,000	1,234	23,800	4,137*	1,300
" 6, A. M...	13,375	3,200	1,750	44,000	1,475	20,400	9,825*	5,200
" 6, P. M...	7,975	1,300	3,975	9,300	945	8,500	12,638	5,500
" 7, A. M...	4,912	800	3,125	6,750	444	16,900	4,037	3,200
" 7, P. M...	4,007	4,400	1,190	7,450	700	3,900	7,212	5,600
" 8, A. M...	1,790	85,000	518	111 000	407	19,200	1,278	12,500
" 8, P. M...	1,190	[illegible]5,000	491	16,000	435	67,200	1,325	12,500

*Abnormal milk.

It will be noted that the number of leucocytes increased greatly in those quarters into which the sterile, distilled water was introduced. The maximum number of leucocytes was found in the second and third milking, 18 to 30 hours after the injection. The number of leucocytes, however, rapidly decreased until by the third day the milk could again be considered as normal. In the case of the left hind quarter the milk at the first and second milking subsequent to injection was abnormal in appearance, containing flocculent matter, consisting largely of fibrin. The milk of the other injected quarter was not abnormal in appearance at any time.

The bacterial content of the milk from the injected quarters showed a marked decrease after the injection, but had again returned to its former condition by the time the leucocyte content had become normal.

In the uninjected quarters no marked change was noted either in leucocytes or bacteria.

EXPERIMENT 2. The same animal was used as in experiment No. 1. Into the quarters not previously injected was introduced a 2 per cent solution of boric acid. The resulting leucocytosis as shown in Table II was not nearly so marked as when sterile distilled water was used. As will be seen from

TABLE II.—EFFECT OF INJECTION OF THE UDDER WITH STERILE 2 PER CENT SOLUTION OF BORIC ACID ON THE LEUCOCYTE AND BACTERIAL CONTENT OF THE MILK. (COW NO. 1.)

DATE.	RIGHT FRONT QUARTER.		RIGHT HIND QUARTER.		LEFT FRONT QUARTER.		LEFT HIND QUARTER.	
	L. per cc.	B. per cc.	L. per cc.	B. per cc.	L. per cc.	B. per cc.	L. per cc.	B. per cc.
	Thousands.		Thousands.		Thousands.		Thousands.	
Dec. 9, A. M.	1,012	34,200	345	70,000	425	8,200	457	14,700
" 9, P. M.	1,190	27,000	1,407	14,600	819	13,600	832	11,100
" 10, A. M.	787	27,500	1,260	8,200	735	6,800	795	80,500
" 10, P. M.	1,032	30,3[illegible]	707	14,[illegible]00	695	20,400	987	33,400
" 11, A. M.	512	20,400	387	17,500	407	46,80[illegible]	57[illegible]	173,000
" 11, M.....	No injection.		Sterile 2% sol. boric acid—300 cc		Sterile 2% sol. boric acid— 50 cc		No injection.	
" 11, P. M.	566	6,800	1,095	1,940	820	19,100	379	30,300
" 12, A. M.	1,125	39,100	3,350	22,500	2,137	35,700	1,727	113,000
" 12, P. M.	815	24,900	1,8[illegible]0	6,500	1,257	34,000	652	115,000
" 13, A. M.	807	63,000	1,052	15,900	907	26,300	840	52,500
" 13, P. M.	1,762	164,500	1,157	15,200	687	11,900	1,045	23,000
" 14, A. M.	862	77,000	687	34,600	562	41,400	1,127	32,500
" 14, P. M.	2,990	27,600	1,1[illegible]7	15,700	1,415	54,100	1,515	23,600

Figure 1, in which the abscissaes represent the observations which, with one exception, were made at 12 hour intervals, and in which the ordinates represent the average leucocyte content in millions of the milk from the injected and uninjected quarters. The bacterial content, which is not represented in graphic form, of the uninjected quarters underwent no marked changes.

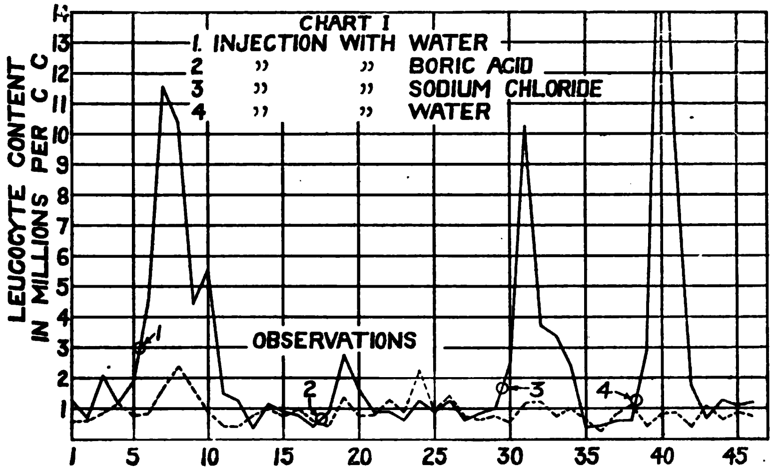


Figure I. Progress of Experimental Leucocytosis in the Udder of Cow No. 1. The solid line indicates injected quarters of udder, the broken line the uninjected quarters.

EXPERIMENT 3. The udder of the animal previously used was injected with 0.6 per cent solution of sodium chloride. The right front and right hind quarters were treated. The milk from both quarters was abnormal. The leucocytosis as measured by the determination of the leucocytes was about

TABLE III.—EFFECT OF INJECTION OF THE UDDER WITH 0.6 PER CENT SOLUTION OF SODIUM CHLORIDE ON THE LEUCOCYTE AND BACTERIAL CONTENT OF THE MILK. (COW NO. 1.)

DATE.	RIGHT FRONT QUARTER.		RIGHT HIND QUARTER.		LEFT FRONT QUARTER.		LEFT HIND QUARTER.	
	L. per cc.	B. per cc.	L. per cc.	B. per cc.	L. per cc.	B. per cc.	L. per cc.	B. per cc.
	Thousands.		Thousands.		Thousands.		Thousands.	
Dec. 15, A. M.	1,425	8,600	550	27 300	1,120	39,500	852	22,200
" 15, P. M.	1,115	5,300	1,440	5,400	1,727	15,000	1,237	8,400
" 16, A. M.	762	41,000	407	79,000	727	19,100	527	49,500
" 16, P. M.	1,075	7,000	6.0	11,600	720	5,400	682	13,400
" 17, A. M.	1,590	22,700	512	14,500	595	10,250	1,162	54,700
" 17, M	Sterile 0.6% sol. NaCl, 150 cc.		Sterile 0.6% sol. NaCl, 300 cc.		No injection.		No injection.	
" 17, P. M	2,825*	525	2,375*	1,000	725	5,675	362	52,500
" 18, A. M.	4,612*	10,150	15,875*	8,900	504	8,500	1,970	42,500
" 18, P. M.	2,687*	1,400	4,850*	400	1,145	6,700	1,477	18,100
" 19, A. M.	3,200*	9,200	3,412*	2,100	895	19,500	702	24,100
" 19, P. M.	1,600	9,500	3,350*	4,800	507	6,700	1,532	16,600

*Abnormal milk.

equal to that found in Experiment No. 1. There was a slight decrease in bacteria. No change in leucocyte or bacterial content was noted in the milk from the uninjected quarters as is shown in Table III.

EXPERIMENT 4. The same animal was again the subject of the experiment. The right front quarter received 300 cc. of sterile distilled water, the right hind quarter 150 cc. The first quarter had been injected twice previously, December 5 with 150 cc. of water, and December 17 with 150 cc. of sodium chloride solution; the second had also been injected twice, December 11 with 300 cc. of boric acid solution, and December 17 with 300 cc. of sodium chloride solution.

It will be noted from Table IV that there was a marked increase in leucocytes, reaching the maximum at the second milking (18 hours) and reaching the normal by the third or fourth day. The milk was abnormal in appearance, as was noted on the previous injection with sterile distilled water. The leucocytosis was very marked, the maximum number of leucocytes found being over twenty million per cc. in the milk of the injected quarters. The bacteria decreased slightly in the milk of the injected quarters.

TABLE IV.—EFFECT OF SECOND INJECTION OF THE UDDER WITH STERILE DISTILLED WATER ON THE LEUCOCYTE AND BACTERIAL CONTENT OF THE MILK. (Cow No. 1.)

DATE.	RIGHT FRONT QUARTER.		RIGHT HIND QUARTER.		LEFT FRONT QUARTER.		LEFT HIND QUARTER.	
	L. per cc.	B. per cc.	L. per cc.	B. per cc.	L. per cc.	B. per cc.	L. per cc.	B. per cc.
	Thousands.		Thousands.		Thousands.		Thousands.	
Jan. 8, P. M..	870	8,800	452	10,200	487	5,600	990	35,600
" 9, A. M..	975	7,800	332	12,900	357	8,[illegible]00	1,820	21,600
" 9, M.....	Sterile distilled water, 300 cc.		Sterile distilled water, 150 cc.		No injection.		No injection.	
" 9, P. M..	3,045	1.350	2.945	3.200	220	5.200	677	14.000
" 10, A. M.	25,400*	1.000	16,950*	4 780	351	15.800	1,512	44.500
" 10, P. M..	11.250*	3.200	7,775*	1.200	281	10.800	1,687	30,300
" 11, A. M..	2.825	15,600	870*	5.400	231	8,600	477	82,000
" 11, P. M..	625	10,100	594	4.200	1,250	14.800	920	30,000
" 12 A. M..	1.077	43.600	1,562	14.100	657	11.800	480	50,000
" 12, P. M..	1,502	42,300	607	14,900	720	48.800	1,032	35,700
" 13, A. M..	1,740	11,400	515	20,300	375	7,600	845	60,000

* Abnormal milk.

From these experiments it is clear that solutions that are considered very inert, such as a warm physiological solution of sodium chloride, have a decided effect on the mammary gland. It can not be concluded that the effect of distilled water is more marked than salt solutions.

TABLE V.—EFFECT OF INJECTION OF THE UDDER WITH A CULTURE OF *B. prodigiosus* ON THE LEUCOCYTE AND BACTERIAL CONTENT OF THE MILK. (Cow No. 1.)

DATE.	RIGHT FRONT QUARTER.		RIGHT HIND QUARTER.		LEFT FRONT QUARTER.		LEFT HIND QUARTER.	
	L. per cc.	B. per cc.	L. per cc.	B. per cc.	L. per cc.	B. per cc.	L. per cc	B. per cc.
	Thousands.		Thousands.		Thousands.		Thousands.	
Jan. 13, P. M..	637	3,300	657	5,100	337	4,600	1,450	12,700
" 14, A. M..	252	36,400	495	16,600	287	11,700	1,125	27,900
" 14, P. M..	602	8,200	337	4,800	407	10,400	502	11,400
" 15, A. M..	787	9,700	450	9,300	500	4,500	412	33,000
" 15, M.....	Culture *B. prodigiosus* 1 cc. diluted to 200 cc.		Culture *B. prodigiosus* 0.5 cc. diluted to 100 cc.		No injection.		No injection.	
" 15, P. M..	....	Numerous	....	Numerous	96	89,000	427	123,000
" 16, A. M..	....	"	....	"	144	233,000	654	35,000
" 16, P. M..	....	"	....	"	401	487,500	1,432	765,000
" 17, A. M..	....	"	....	"	1,262	72,000	....	306,500
" 17, P. M..	....	"	....	"	827	17,200	1,132	320,000
" 1 , A. M..	....	"	....	"	1,152	33,700	2,050	67,000
" 18, P. M..	....	86,500	....	93,000	1,095	10,300	745	29,500
" 19, A. M..	....	124,500	....	67,000	445	18,000	219	37,000
" 19, P. M..	690	392,000	641	17,000	207	11,100	962	264,000
" 20, A. M..	632	808,000	675	19,400	419	19,800	815	86, 00
" 20, P. M..	3,015	101,000	1,302	10,800	407	14,400	987	20,600
" 21, A. M..	532	80,000	850	9,000	287	236,000	600	15,400
" 21, P. M..	3,740	91,000	1,980	7,500	369	4,600	715	27,200
" 22, A. M..	2,015	106,000	1,505	38,700	970	11,500	575	108,000
" 22, P. M..	800	268,000	81	6,500	790	10,900	194	20,700
" 23, A. M..	1,175	272,000	1,615	15,100	1,325	8,200	1,430	33,100
" 23, P. M..	1 700	13,600	650	13 500	750	6,200	1,250	38,400
" 24, A. M..	790	13,600	750	10,600	665	5,900	800	26,000
" 24, P. M..	590	21,500	627	27,200	402	16,300	612	57,000
" 25, A. M..	632	58,000	395	14,400	312	18,600	365	49,700

EXPERIMENT 5. The same quarters as were injected in Experiment 4 were now injected with 0.5 cc. of a broth culture of *B. prodigiosus* in 100 cc. of sterile water, and 1 cc. of the culture in 200 cc of water respectively. The quarters had both been injected three times previously. As will be noted from the Table V, the resulting changes were most marked. The milk secretion was practically stopped, less than six ounces was obtained at the first milking after injection from the uninjected quarters, and none from the injected. There was a

marked inflammation of the entire udder and a general constitutional illness. Recovery was rapid. By the third milking it was possible to obtain a few streams of a watery, yellowish clotted liquid from the injected quarters. The milk was so abnormal that no determinations of leucocytes could be made until the eighth milking.

The changes resulting from the injection of the culture of *B. prodigiosus* were much more marked than in previous injections with sterile solutions. It is somewhat doubtful whether the organism alone was the cause. The effect of the water may have been intensified by the organisms. It should also be remembered that both quarters had been injected three times previously. It may be that they were more sensitive than if they had not been so treated.

Colonies of *B. prodigiosus* were very numerous on the plate cultures. No accurate determinations were made until the third day after the injection, as will be noted from Table V. Few other organisms than *B. prodigiosus* were found. The organisms introduced had largely disappeared by the eighth day, only scattering colonies were found after that time. Whether actual multiplication took place in the udder is uncertain, although the high counts obtained on the fourth and fifth days after injection would seem to indicate that multiplication may have occurred. Previous investigators have found that the same organism, *B. prodigiosus* could not persist for long periods in the udder. Ward[4] was unable to find the organism six days after injection into the udder. Russell and Hastings[5] were able to detect the presence of the organism in small numbers for 22 days. The animal had, however, been previously injected, and the culture produced a marked case of garget. With a more normal gland the period of persistence may have been very different. It is also to be noted from Table V that the bacterial content of the milk from the uninjected quarters was greatly increased.

FURTHER EXPERIMENTS. A portion of the experiments already described were repeated with another cow. The detailed results are given in Tables VI, VII, and VIII, and are repre-

[4] Jour. Appl. Micros., 1898, 1: 205.
[5] Wis. Agri. Expt. Sta., 21st Ann. Rpt., 1904, p. 164.

sented in graphic form in Figure 2. It will be noted that the results are similar to those obtained with cow No. 1. A marked leucocytosis was produced by each injection, followed by a rapid return to the normal.

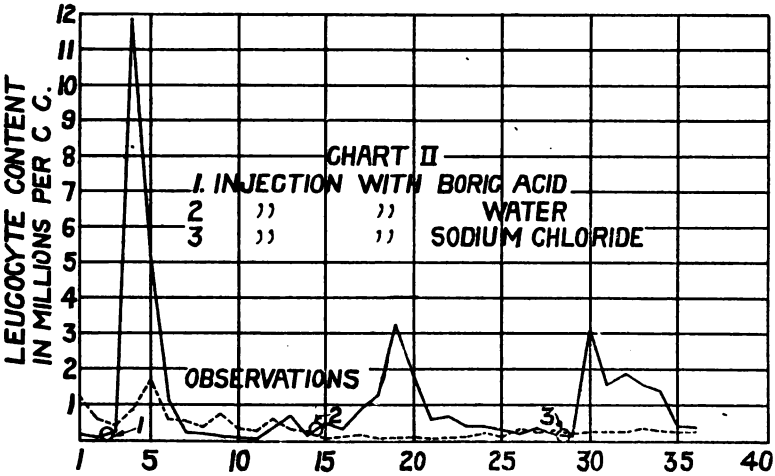


Figure II. Progress of Experimental Leucocytosis in the Udder of Cow No. 2. The solid line indicates injected quarters of the udder, the broken line the uninjected quarters.

TABLE VI.—EFFECT OF INJECTION OF THE UDDER WITH STERILE 2 PER CENT SOLUTION OF BORIC ACID UPON THE LEUCOCYTE AND BACTERIAL CONTENT OF THE MILK. (COW NO. 2).

DATE.	RIGHT FRONT QUARTER.		RIGHT HIND QUARTER.		LEFT FRONT QUARTER.		LEFT HIND QUARTER.	
	L. per cc.	B. per cc.	L. per cc.	B. per cc.	L. per cc.	B. per cc.	L. per cc.	B. per cc.
	Thousands.		Thousands.		Thousands.		Thousands.	
Jan. 8, P. M..	1,937	11,100	160	55	637	2,700	6	4,900
" 9, A. M..	591	270	25	105	526	3,500	6	810
" 9, M.....	No injection.		Sterile 2% boric acid sol., 300 cc.		No injection.		Sterile 2% boric acid sol., 150 cc.	
" 9. P. M..	229	82,509	107	500	442	200	366	65
" 10, A. M..	1,100	6,900	5,640*	90	726	4,100	18,250*	29
" 10, P. M..	1,890	200	3,332*	55	1,677	100	7,375*	20
" 11, A. M..	670	800	625	45	700	400	1,687*	10
" 11, P. M..	675	200	469	10	501	1,800	577	0
" 12, A. M..	437	300	326	500	251	1,000	262	30
" 12, P. M..	1,045	300	175	60	415	300	382	35
" 13, A. M..	416	300	125	400	375	140	194	150
" 13, P. M..	370	500	106	100	172	200	81	100

*Abnormal milk.

TABLE VII.—EFFECTS OF INJECTION OF THE UDDER WITH STERILE DISTILLED WATER UPON THE LEUCOCYTE AND BACTERIAL CONTENT OF THE MILK. (Cow No. 2.)

DATE.	RIGHT FRONT QUARTER.		RIGHT HIND QUARTER.		LEFT FRONT QUARTER.		LEFT HIND QUARTER.	
	L. per cc.	B per cc.	L. per cc.	B, per cc.	L. per cc.	B. per cc.	L. per cc.	B. per cc.
	Thousands.		Thousands.		Thousands.		Thousands.	
Jan. 14, A. M..	439	180	50	460	476	150	67	220
" 14, P. M..	869	50	42	80	682	60	37	30
" 15, A. M..	244	210	465	190	36	500	31	730
" 15, M.....	Sterile distilled water, 300 cc.		No injection.		Sterile distilled water, 150 cc.		No injection.	
" 15, P. M..	108*	110	41	90	907	260	19	200
" 16, A. M..	225	390	56	230	345	430	44	150
" 16, P. M..	430*	180	117	300	1,500	820	27	100
" 17, A. M..	812*	850	33	420	1,725	140	31	220
" 17, P. M..	4,770*	280	72	40	1,677	20	17	100
" 18, A. M..	1,387*	70	89	200	2,562	240	16	150
" 18, P. M..	387	370	12	220	864	80	12	170
" 19, A. M..	795	50	37	650	702	90	16	170
" 19, P. M..	437	210	145	170	375	100	16	70
" 20, A. M..	625	120	256	2,800	75	440	154	300
" 20, P. M..	381	70	129	240	11	100	16	1,400

*Abnormal milk.

TABLE VIII.—EFFECT OF INJECTION OF THE UDDER WITH A STERILE 0.6 PER CENT SOLUTION OF SODIUM CHLORIDE. (Cow No. 2.)

DATE.	RIGHT FRONT QUARTER.		RIGHT HIND QUARTER.		LEFT FRONT QUARTER.		LEFT HIND QUARTER.	
	L. per cc.	B. per cc.	L. per cc.	B. per cc.	L per cc.	B. per cc.	L. per cc.	B. per cc.
	Thousands.		Thousands.		Thousands.		Thousands.	
Jan. 21, A. M..	331	500	154	910	191	740	94	....
" 21, P. M..	420	170	147	280	274	390	21	1,190
" 22, A. M..	347	6,160	127	3,900	216	1,[illegible]50	14	3,440
" 22, M.....	No injection.		Sterile 0.6% NaCl sol., 300 cc.		Sterile 0.6% NaCl sol., 150 cc.		No injection.	
" 22, P. M..	76	5,300	7	280	27	11,800	3	1,470
" 23, A. M..	507	350	3,687	220	2,625	3,630	17	470
" 23, P. M..	282	100	1,430	80	1,607	1.890	11	660
" 24, A. M..	352	3,270	2,025	190	1.787	2,700	16	1,590
" 24, P. M..	565	140	790	190	1,425	270	16	180
" 25, A. M..	360	450	850	250	1,040	2,080	10	1,260
" 25, P. M..	185	2.150	425	250	350	7,800	17	150
" 26, A. M..	282	1,040	300	1,030	432	230	8	2,040

GENERAL DISCUSSION OF RESULTS.

It will be noted from the tables that an increased leucocyte content is often accompanied by a decrease in bacteria (Table VI). In the uninjected quarters the leucocyte content was unchanged, and also the bacterial content. The decrease in number of bacteria may be due to the phagocytic action of the leucocytes. A microscopical examination of the sediment from the milk of the injected quarters showed many leucocytes containing from 5 to 25 bacteria, while the sediment from the uninjected quarters showed no such action.

To explain this interesting phenomenon, one must remember that the leucocytes as found in the udder at this time, particularly in the injected quarters, are in an active state and possess the power of phagocytosis to a high degree. Where the number of such leucocytes is so markedly increased, as occurred in the injected quarters, phagocytosis should be more energetic than in the uninjected quarters, in which the leucocyte content remained normal or at the most showed but a slight increase. This accumulation of active phagocytic leucocytes should accordingly cause the destruction of many of the bacteria in the injected quarters, whereas in the uninjected quarters, the bacterial content should remain constant or show an increase. Such, as is evident from the tables, actually occurred to a greater or less extent in every case where sterile solutions were injected.

In the abnormal milk the presence of flocculent material was always noted. Examination of these clots, which were of a doughy consistency and which invariably rose to the surface of the liquid, revealed them to be comprised almost entirely of large masses of fibrin strands. It is well to remark here that in all instances immediately following injection, it was possible to demonstrate by staining and subsequent microscopic examination the presence of fibrin. Such was invariably the case whether or not there were any physical evidences of the existence of fibrin in the milk at time of withdrawal. Its presence could be detected as long as the increased leucocyte content resulting from the injection persisted.

From the standpoint of milks which show an abnormally high leucocyte content, this relation of fibrin to leucocytes is of importance, for it enables one to determine whether the leu-

cocytosis is normal or due to an inflammatory condition. Previous studies have shown that those milks which are high in leucocytes, but which come from perfectly normal cows, do not as a rule contain fibrin. Accordingly it appears important, in condemning milks for alleged pus to take into consideration the presence or absence of fibrin and not necessarily to condemn milk on the basis of a high leucocyte content alone.

In conclusion it may be well to mention the results obtained on making acid determinations of the milks from the individual quarters. Whereas, before injection the acidity of this milk was practically the same in all quarters, subsequent thereto considerable differences were found. In most cases the milk from the uninjected quarters showed more acidity than that from the uninjected. This was true only immediately subsequent to injection, and gradually disappeared. Furthermore, the more marked the leucocytosis, the greater was this difference in acidity. The decreased acidity is undoubtedly due to the presence of blood serum in the milk.

CONCLUSIONS.

The injection of such inert solutions as a physiological salt solution, boric acid, and distilled water produce a rapid and marked leucocytosis, as is shown by the swelling and fever of the quarters injected, and by the increased content in leucocytes of the milk from such quarters. Such a leucocytosis persists for only a short time. The sensitiveness of the mammary gland to foreign substances is emphasized by these results.

INDEX.

Note: The two Reports of the Director and the Research Bulletins herewith bound together are paged separately. References to each report are indicated, the other numbers referring to the Research Bulletins, which are paged through No. 1 to 6 inclusive.

A

B

H

I

J

L

M

U

W

Y